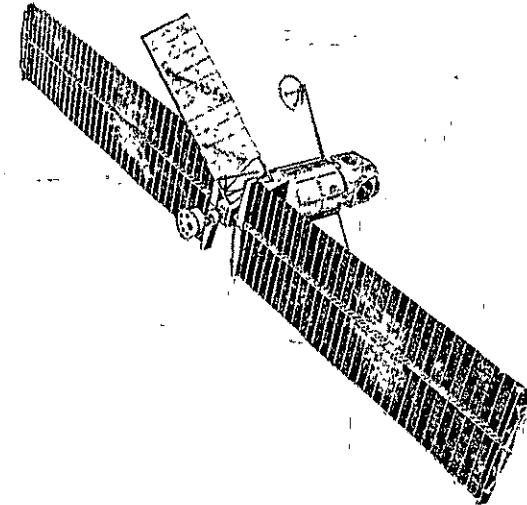




(NASA-CR-161149) THE 25 kW POWER MODULE  
EVOLUTION STUDY. PART 3: CONCEPTUAL  
DESIGNS FOR POWER MODULE EVOLUTION. VOLUME  
5: MISSION ACCOMMODATIONS Final Report  
(Lockheed Missiles and Space Co.) 216 p HC

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**NASA**

George C. Marshall  
Space Flight Center

## 25 kW POWER MODULE EVOLUTION STUDY

VOLUME 5 MISSION ACCOMMODATIONS  
PART III : CONCEPTUAL DESIGNS FOR POWER MODULE EVOLUTION • FINAL REPORT

LOCKHEED MISSILES & SPACE COMPANY, INC.

LMSC-D614944-5

FINAL REPORT  
25 kW POWER MODULE EVOLUTION STUDY  
PART III: CONCEPTUAL DESIGNS FOR POWER MODULE EVOLUTION  
VOLUME 5: MISSION ACCOMMODATIONS  
27 JANUARY 1979

Submitted to the  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
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DPD 555  
DR NO. MA-04

LOCKHEED MISSILES & SPACE COMPANY, INC.  
SUNNYVALE, CALIFORNIA

## FOREWORD

This volume of the Part III Final Report for the 25 kW Power Module Evolution Study was prepared by Lockheed Missiles & Space Company, Inc. for the George C. Marshall Space Flight Center (MSFC), National Aeronautics and Space Administration (NASA), under Contract No. NAS8-32928.

The objective of the study was to define how the 25 kW Power Module can be evolved by the addition of system elements in evolutionary steps to meet the future mission requirements. For each step, conceptual designs were prepared. The level of capability at each step was commensurate with the mission and payload requirements. Emphasis was placed on the near-term steps beyond the 25 kW Power Module.

The study activity comprised the following parts/tasks:

- Part I – Payload Requirements and Growth Scenarios (LMSC, TRW, and Bendix)

This analytical effort was conducted to develop payload application summaries and time-phased requirements that will drive the concepts for the 25 kW Power Module and the supporting systems definitions (for the period 1983-1990). The Part I effort was documented in Final Report LMSC-D614921A, dated 1 August 1978.

- Part II – Payload Support System Evolution (LMSC, IBM, and Bendix)

This effort was devoted to establishing baseline program support elements and candidate evolutionary growth capabilities for final candidate definition (element data, cost, mods, development sequence, and precursor missions). The Part II effort was documented in Final Report LMSC-D614928A, dated 30 September 1978.

● Part III – Conceptual Designs for Power Module Evolution (LMSC, Bendix)

This effort was conducted to establish design approaches for the evolutionary systems, to develop associated programmatics data, and to assess the evolution scenario and capabilities of the 25 kW Power Module for representative missions.

This report constitutes Volume 5, Mission Accommodations, of the Part III Final Report. It meets the requirements of Contract No. NAS8-32928 Data Procurement Document, Data Requirement MA-04, Final Study Report.

The volumes comprising the Part III Final Report are:

- |                                     |                                     |
|-------------------------------------|-------------------------------------|
| ● Volume 1 – Power Module Evolution | ● Volume 4 – Design Analyses        |
| ● Volume 2 – Program Plans          | ● Volume 5 – Mission Accommodations |
| ● Volume 3 – Cost Estimates         | ● Volume 6 – WBS and Dictionary     |

## ACKNOWLEDGEMENTS

This report is the product of the efforts of an integrated team with skills in a variety of technical specialties. Their contributions are gratefully acknowledged.

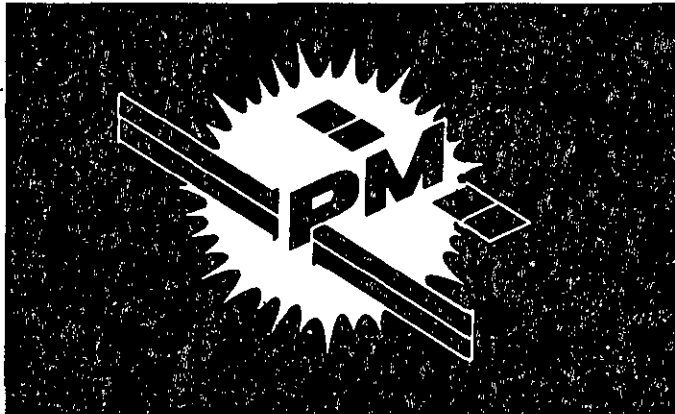
|                               |                                                                                                                        |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Mission Program Accommodation | H. F. Shodiss, T. P. Luck                                                                                              |
| Power Module Capabilities     | M. A. Krop, R. C. Chao, E. D. Webb<br>P. E. Schroeder, R. W. Given,<br>R. A. Barsocchi (Bendix), R. Kaczynski (Bendix) |
| STO Mission Accommodation     | T. P. Luck, W. W. Hutchins,<br>J. E. Evans, R. G. Johnson                                                              |
| STO Sample Experiment         | J. E. Evans, J. L. Reitman,<br>C. W. Stevens                                                                           |
| MPS Mission Accommodation     | R. A. Barsocchi (Bendix),<br>J. L. Reitman, H. Posnansky                                                               |
| Stellar Mission Accommodation | J. E. Evans, C. W. Stevens,<br>R. C. Catura                                                                            |

The Mission Accommodation Analysis task was led by L. L. Giller under the direction of J. W. Overall, Manager of the 25 kW Power Module Evolution Study.

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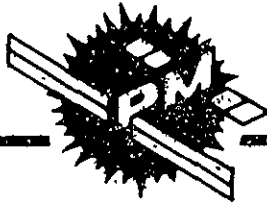


## SECTION 1. INTRODUCTION

“ACCOMMODATIONS ANALYSIS ROLE IN STUDY

- This chart is self explanatory.





## ACCOMMODATIONS ANALYSIS ROLE IN STUDY

---

- ASSESS SCENARIO SATISFACTION OF DISCIPLINE REQUIREMENTS
- ASSESS CAPABILITY OF 25 kW POWER MODULE  
TO CONDUCT REPRESENTATIVE MISSIONS WHICH  
INCLUDE EARTH, SOLAR, STELLAR, AND ZERO – G  
EXPERIMENTS
- UTILIZE REQUIREMENTS FROM PART I OF STUDY
- INPUT FINDINGS FOR PART II/III ANALYSES OF  
SELECTED CONFIGURATION CAPABILITY

### ACCOMMODATIONS ANALYSIS

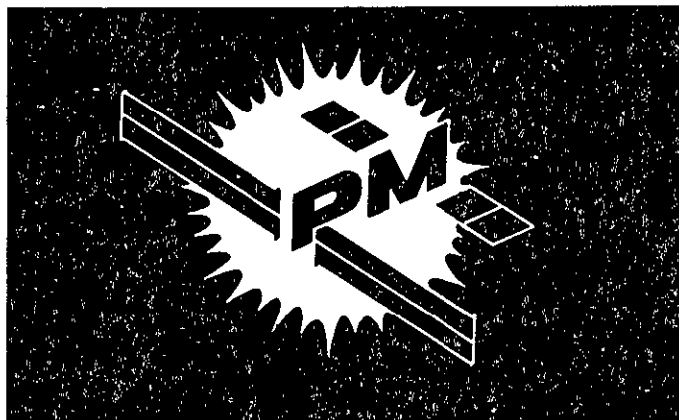
- This chart provides a general statement of the analysis tasks.
- It is important to note that the mission requirements analysis deals with the evolutionary aspects of the study, whereas the mission evaluation relates to the capabilities of the 25 kW Power Module.



# ACCOMMODATIONS ANALYSIS

---

- MISSION REQUIREMENTS ACCOMMODATION
  - EVALUATE ABILITY OF POWER MODULE EVOLUTION SCENARIO TO SATISFY USER NEEDS
  
- MISSION CAPABILITIES EVALUATION
  - EVALUATE ABILITY OF THE 25 kW POWER MODULE DESIGN TO SUPPORT DESIGNATED USER MISSIONS



## SECTION 2

# MISSION REQUIREMENTS ACCOMMODATION

- 2.1 METHODOLOGY
- 2.2 SCENARIO
- 2.3 REQUIREMENT SATISFACTION

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## 2.1 METHODOLOGY

### MISSION ANALYSIS METHODOLOGY

- This chart depicts the methodology used in performing the program accommodations analysis. It specifically compares requirements against growth scenarios established in Parts II and III of the Study.



## MISSION ANALYSIS METHODOLOGY

---

- DELINEATE SUPPORT REQUIREMENTS FOR EACH DISCIPLINE AS A FUNCTION OF ORBIT AND YEAR
  - POWER/HEAT REJECTION
  - ATTITUDE CONTROL
  - COMMAND AND DATA HANDLING
- DEFINE SYSTEM CAPABILITIES AS A FUNCTION OF ORBIT AND YEAR
- COMPARE CAPABILITIES WITH REQUIREMENTS AND EVALUATE REQUIREMENT SATISFACTION

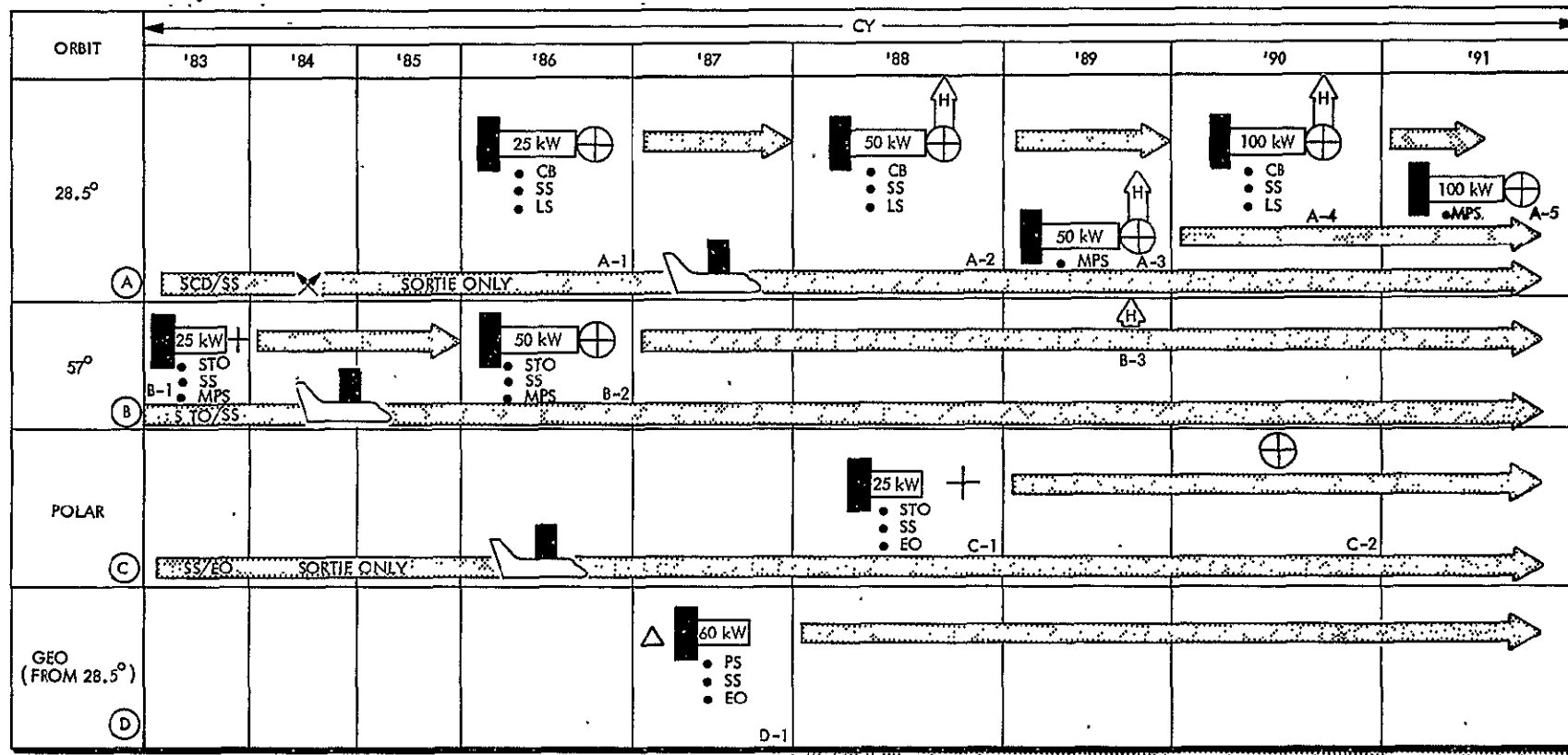
## 2.2 SCENARIO

### PROGRAM SCENARIO 1

- PM composite requirements scenarios were constructed, based on mission requirements in Part 1. LEO orbit inclinations of  $28.5^{\circ}$  (max payload),  $57^{\circ}$  (max inclination from ETR), and  $90^{\circ}$  (world-wide coverage) were selected for analysis. Geostationary orbit was selected for its special utility in "public service" applications.
- General Groundrules - All Scenarios
  - The 1st PM will be available in 1983 for the  $57^{\circ}$  orbit.
  - PM docking with the SKYLAB will be achievable by 1984.
  - MPS avoids sharing PM with construction activity in  $28.5^{\circ}$ .
  - Extended use of PMs is a goal, particularly for the minimum scenarios.
  - PEP is available for shuttle sortie from 1983-1990.
  - PM in GEO is a derivative of the basic 25 kW PM.
- Specific Groundrules - Nominal Scenario 1 - Structured to minimize peak funding.
  - Power Module availability:
    - In  $28.5^{\circ}$  orbit 25 kW - 1986; 50 kW - 1988; 100 kW - 1990; 100 kW - 1991
    - In  $57^{\circ}$  orbit 25 kW - 1983; 50 kW - 1986
    - In polar orbit 25 kW - 1988
    - In GEO orbit 60 kW (25 kW derivative) - 1987



# PROGRAM SCENARIO I (NOMINAL – NO SKYLAB)



|  |                                             |
|--|---------------------------------------------|
|  | POWER MODULE                                |
|  | DOCKING MODULE – UNPRESS                    |
|  | DOCKING/WORKSHOP MODULE – PRESS             |
|  | 15 kW SORTIE ONLY – PEP AVAILABLE ALL YEARS |
|  | MANNED HABITAT – FREE-FLYER MODE            |
|  | REQUIRES PAYLOAD STABILIZATION KIT          |
|  | 25 kW DERIVATIVE HARDWARE                   |
|  | SKYLAB                                      |

- MP – MATERIAL PROCESSING
- STO – SOLAR TERRESTRIAL OBSER.
- PS – PUBLIC SERVICE
- SS – SPACE SCIENCE
- EO – EARTH OBSERVATION
- CB – CONSTRUCTION BASE FOR:
  - SPS – SPACE POWER SYSTEM
  - GEO PLATFORM
  - LEO PLATFORM
  - OTHERS
- SCD – SPACE CONSTRUCTION DEMO
- LS – LIFE SCIENCE

IMPROVED PM  
EFFICIENCY  
WITH ADVANCED  
TECHNOLOGY  
POSSIBLE

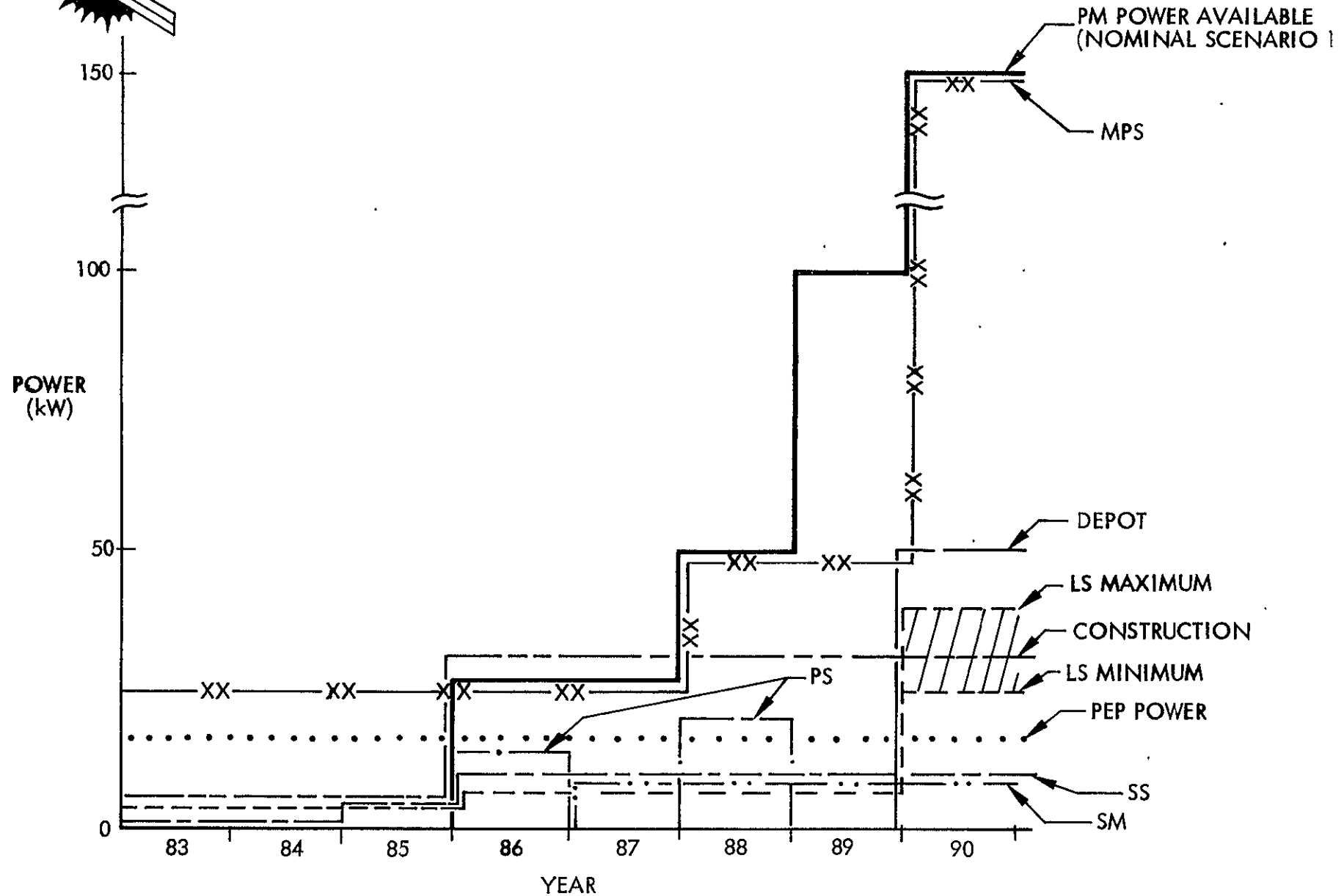
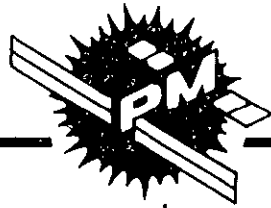


### 2.3 REQUIREMENTS SATISFACTION

#### USER REQUIREMENTS SATISFACTION 28.5° ORBIT

- The next 3 charts represent the individual discipline requirements in 28.5°, 57°, and polar orbits from 1983 through 1990, and the power (PM and PEP) available in each orbit.
- For the 57° orbit, the individual discipline requirements are satisfied since they fall below the PM power available. However, in 28.5° and polar orbits, the Power Module power available is less than required. Early year material processing requirements will be satisfied by shifting the mission to 57°.
- Other early-year power requirements in 28.5° and polar orbits can be satisfied by time and power sharing among the disciplines and by using PEP. It appears, however, that it will be necessary to delay some ambitious polar missions.
- No attempt was made to plan in detail the flight missions for these experiments. However, it is clear that time and power sharing among the disciplines on the Power Module or PEP support will be required. Resource allocation to disciplines is considered to be beyond the scope of this study.

# USER REQUIREMENTS SATISFACTION 28.5° ORBIT



USER REQUIREMENTS SATISFACTION  
57° ORBIT

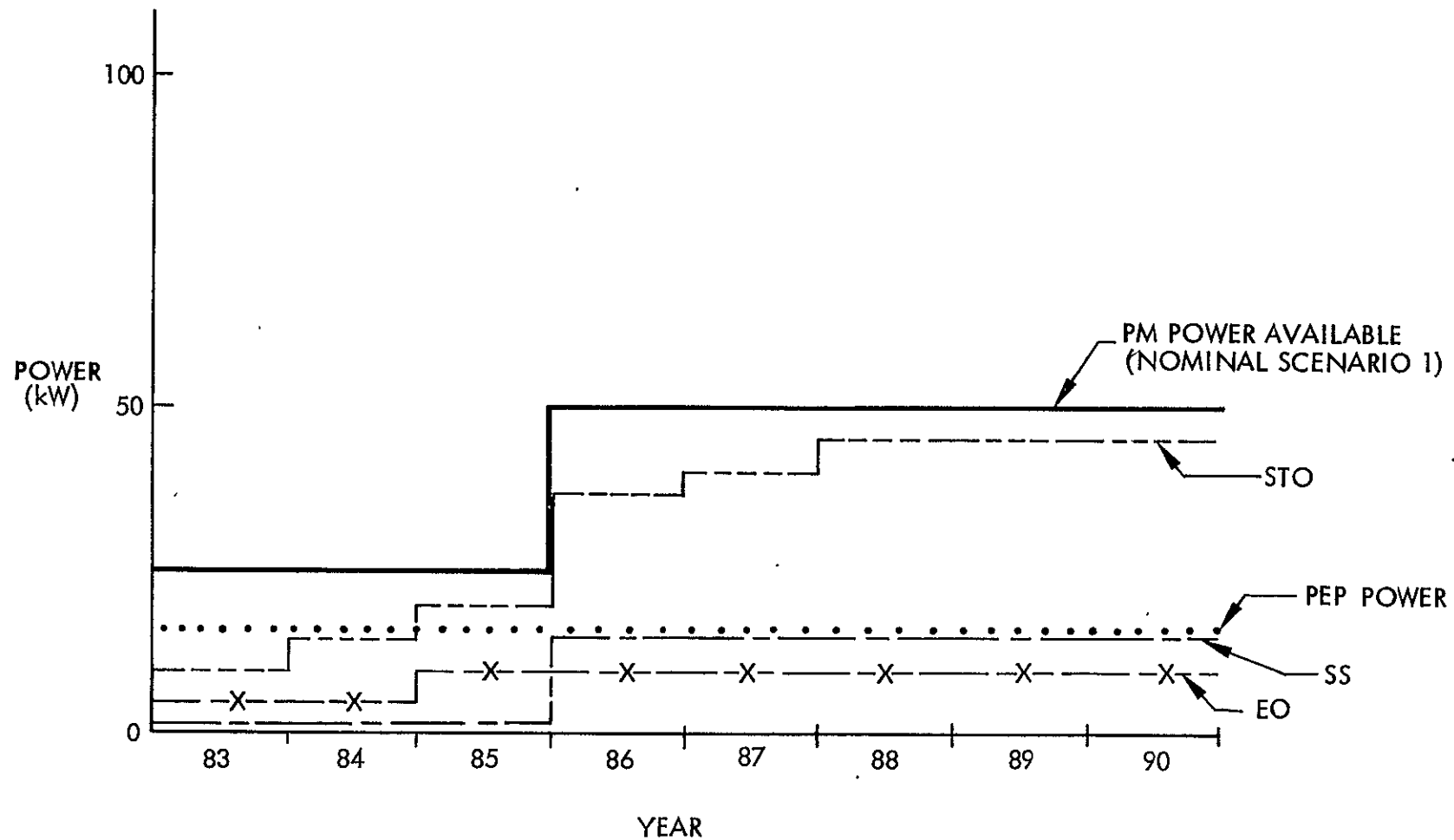
- Refer to discussion with the preceding chart.



# USER REQUIREMENTS SATISFACTION

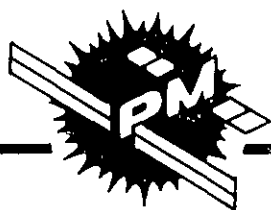
## 57° ORBIT

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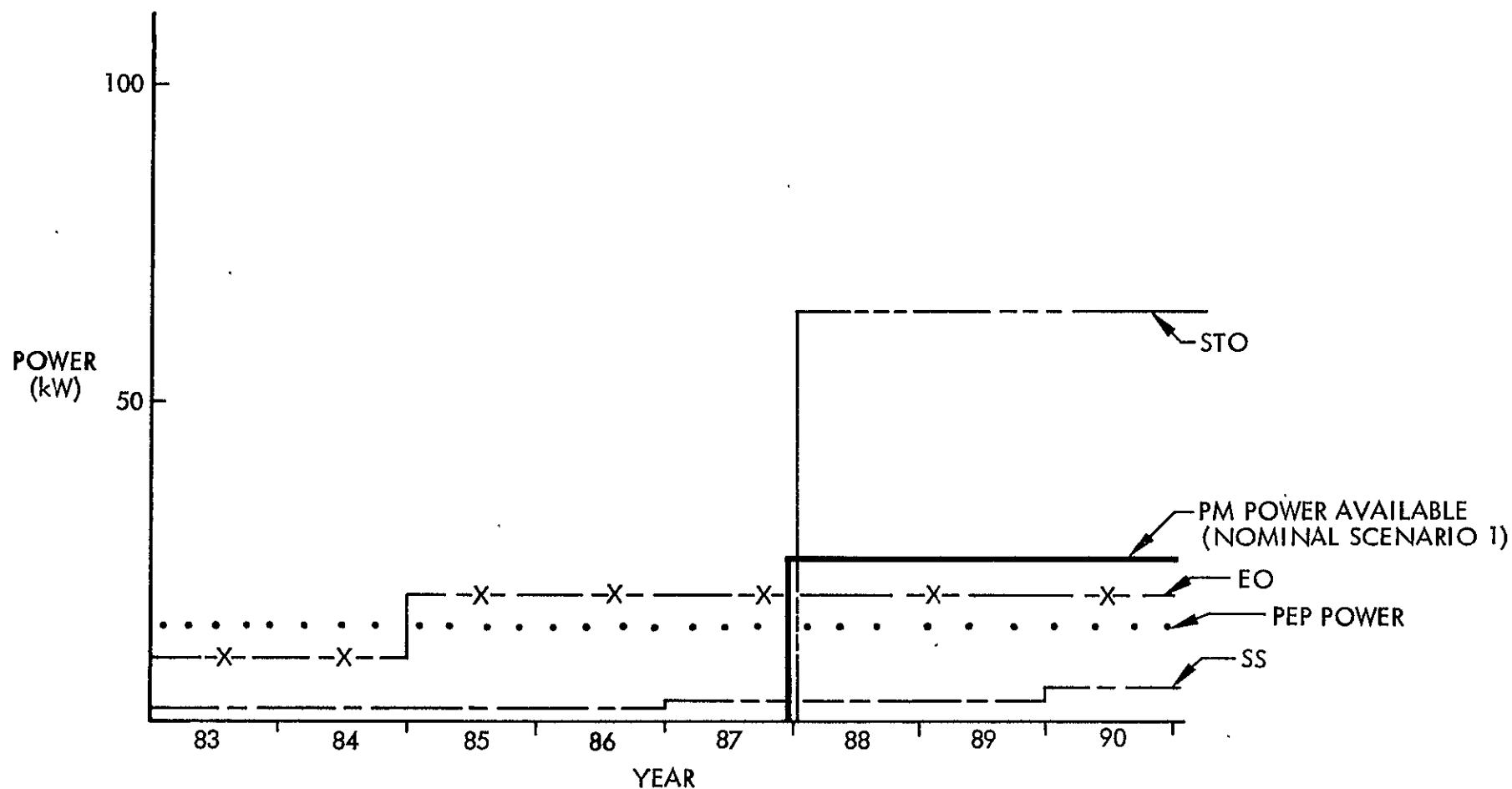


USER REQUIREMENTS SATISFACTION  
POLAR ORBIT

- Refer to discussion with the two preceding charts.

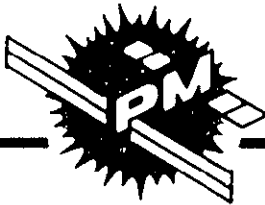


# USER REQUIREMENTS SATISFACTION POLAR ORBIT



### USER REQUIREMENTS SATISFACTION SUMMARY

- This chart presents summary data on the degree to which the evolving Power Module satisfies the stated needs of users.

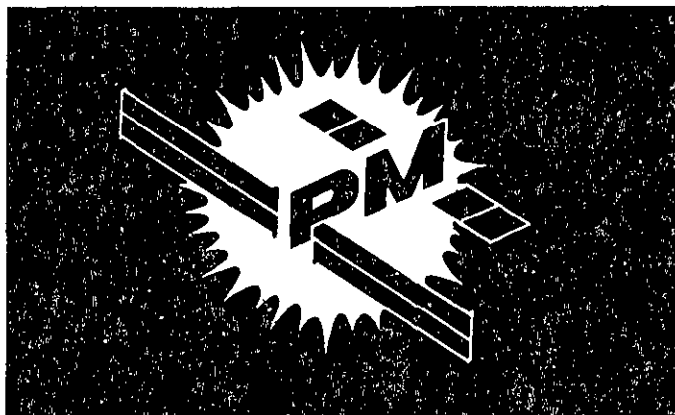


## USER REQUIREMENTS SATISFACTION SUMMARY

---

- ELECTRIC POWER
  - REQUIREMENTS FOR EACH DISCIPLINE ARE MET IN 28.5° AND 57° ORBITS
  
- HEAT REJECTION
  - SORTIE MISSIONS PAYLOAD NEEDS SATISFIED
  - 25 AND 50 kW POWER MODULE RADIATORS SIZED TO REJECT  $\approx 40\%$  OF PAYLOAD ENERGY
  - DEDICATED THERMAL MODULE RECOMMENDED FOR LARGER POWER MODULES FOR PAYLOAD HEAT REJECTION
  
- ATTITUDE CONTROL
  - POINTING MODES TO SATISFY MISSION NEEDS ARE ACHIEVABLE
  - POWER MODULE ACCURACY AND STABILITY WILL MEET OR EXCEED ORBITER PERFORMANCE REQUIREMENTS
  - $10^{-5}$  G LEVEL ATTAINABLE
  
- COMMAND AND DATA HANDLING
  - DETAILED MISSION REQUIREMENTS WILL BE MET (TIME SHARING REQUIRED)





## SECTION 3

# MISSION CAPABILITIES EVALUATION

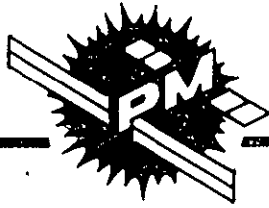
- 3.1 METHODOLOGY
- 3.2 POWER MODULE CHARACTERISTICS
- 3.3 MISSION ACCOMMODATION ASSESSMENTS
- 3.4 ACCOMMODATIONS SUMMARY

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### 3.1 METHODOLOGY

#### TASK OVERVIEW

- This chart presents an overview of the mission accommodations task. The task was intended to examine the 25 kW Power Module as designed and to assess its ability to support the missions contemplated for it, both in the sortie mode and as a free flyer. A secondary function was to provide data on the contribution of the power module to mission capability.
- The evaluation utilized a "minimum" power module, functionally equivalent to the MSFC Phase A baseline, as the point of departure. Vehicle variations involving augmentation of subsystems were considered, when appropriate, in the analysis. Refer to Vol 1, Section 4 for a description of the vehicle.



## TASK OVERVIEW

---

- TO VERIFY ABILITY OF 25 kW POWER MODULE TO SATISFY IDENTIFIED MISSION REQUIREMENTS
- TO EVALUATE ABILITY OF 25 kW POWER MODULE TO IMPROVE MISSION CAPABILITY
  - INCREASED POWER/HEAT REJECTION
  - EXTENDED MISSION DURATION
  - LONGER OBSERVATIONS
  - IMPROVED OBSERVATION CONDITIONS
- EXPERIMENT DISCIPLINES ANALYZED
  - SOLAR TERRESTRIAL OBSERVATORY (STO)
  - STELLAR OBSERVATION
  - MATERIALS PROCESSING/LIFE SCIENCES
- OPERATING MODES CONSIDERED
  - SHUTTLE SORTIE
  - PEP-SUPPORTED ORBITER SORTIE
  - PM SUPPORTED ORBITER SORTIE
  - PM SUPPORTED FREE-FLYER
- POWER MODULE VEHICLE VARIATIONS CONSIDERED
  - MINIMUM VEHICLE
  - AUGMENTED ATTITUDE CONTROL SYSTEM (ACS)
  - MODIFIED ELECTRICAL POWER SYSTEM (EPS)
  - SCIENTIFIC DATA COMMAND AND DATA HANDLING (C&DH)

### OPERATING MODE DEFINITIONS

- In the interests of clarity, this chart defines the operating modes as used in the analysis.



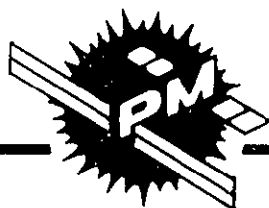
## OPERATING MODE DEFINITIONS

---

- SHUTTLE SORTIE: PAYLOAD CARRIED TO AND SUPPORTED ON ORBIT BY ORBITER
- PEP SUPPORTED SORTIE: PAYLOAD AND PEP ARRAY CARRIED TO ORBIT BY ORBITER, WITH PEP AUGMENTING ORBITER SUPPORT OF PAYLOAD ON ORBIT
- PM SUPPORTED SORTIE: ORBITER AND PAYLOAD DOCKED TO POWER MODULE FOR ORBITAL OPERATIONS
- FREE FLYER: PAYLOAD DOCKED TO AND SUPPORTED BY POWER MODULE

## OPERATING MODE OVERVIEW

- This chart provides a functional description of the operating modes. There are several implicit assumptions in these descriptions which should be validated in later, more detailed analyses:
  - The orbiter attitude sensors can be used to provide attitude reference data to the power module in sortie operations. This implies detailed technical compatibility and that the orbiter sensor is not blocked from its required observations by the power module.
  - The heat to be rejected can be efficiently divided between power module and orbiter radiators.



## OPERATING MODE OVERVIEW

| OPERATING<br>MODE<br><br>FUNCTION | SHUTTLE SORTIE                                     | PEP SUPPORTED<br>SORTIE                                                          | PM SUPPORTED SORTIE                   |                                                                                | FREE-FLYER                                                         |
|-----------------------------------|----------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------|
|                                   |                                                    |                                                                                  | LONG DURATION<br>MODE                 | HIGH POWER<br>MODE                                                             |                                                                    |
| PAYLOAD<br>ELECTRIC<br>POWER      | ORBITER FUEL<br>CELLS                              | PEP ARRAY<br>AUGMENTED<br>FUEL CELLS IN<br>SUNLIGHT,<br>FUEL CELLS IN<br>ECLIPSE | PM SOLAR ARRAY<br>+ BATTERIES         | PM ARRAY<br>AUGMENTED<br>FUEL CELLS<br>IN SUNLIGHT<br>FUEL CELLS<br>IN ECLIPSE | PM SOLAR ARRAY                                                     |
| PAYLOAD<br>HEAT<br>REJECTION      | ORBITER RADI-<br>ATORS AND<br>FLASH<br>EVAPORATORS | ORBITER RADI-<br>ATORS AND<br>FLASH<br>EVAPORATORS                               | ORBITER RADIATORS AND PM<br>RADIATORS |                                                                                | PM RADIATORS<br>P/L RADIATORS                                      |
| ATTITUDE<br>CONTROL               | ORBITER RCS/VCS                                    | ORBITER RCS/VCS                                                                  | POWER MODULE CMGs                     |                                                                                | POWER MODULE<br>CMGs                                               |
| ATTITUDE<br>REFERENCE             | ORBITER SENSOR                                     | ORBITER SENSOR                                                                   | ORBITER SENSOR                        |                                                                                | CONFIGURATIONS<br>EXAMINED WITH<br>AND WITHOUT<br>ATTITUDE SENSORS |

## MISSION CAPABILITIES OVERVIEW

- This chart presents a summary of the mission accommodations related technical characteristics of the various operating modes. A shuttle sortie mission is limited in payload power provided, mission duration, and heat rejection under some circumstances, and uses an attitude control system that produces contamination and attitude disturbances that can interfere with observations.
- Addition of PEP increases mission duration to at least 11 days, increases payload power, and improves payload heat rejection by reducing orbiter fuel cell waste heat.
- The PM supported sortie provides 11 kW payload power (although some attitude - beta combinations will be deficient in power), increases mission duration to 30 to 60 days (limited by the orbiter), improves heat rejection capability, and provides a non-disruptive attitude control system. Alternatively the PM, operating to augment the orbiter fuel cells, can supply 19 kW for 17 days.
- The PM free-flyer provides a capability for a mission duration limited only by the mission equipment, provides 25 kW to the mission equipment, and provides non-disruptive attitude control with hold durations increased over those achievable in sortie mode due to the elimination of the necessity for the power module ACS to control the additional mass of the orbiter.





## MISSION CAPABILITIES OVERVIEW

| OPERATING MODE<br>CAPABILITY | SHUTTLE SORTIE                                                                                                      | PEP SUPPORTED SORTIE                                                                                                 | PM SUPPORTED SORTIE                                                                    |                                                                                 | FREE-FLYER                                 |
|------------------------------|---------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|--------------------------------------------|
|                              |                                                                                                                     |                                                                                                                      | LONG DURATION MODE                                                                     | HIGH POWER MODE                                                                 |                                            |
| MISSION DURATION*            | LIMITED BY ORBITER EXPENDABLES FOR ~5 DAYS MINIMUM                                                                  | LIMITED BY ORBITER EXPENDABLES. 11-17 DAYS DEPENDING ON SOLAR BETA AND PAYLOAD POWER LEVEL (4 KIT CRYOGENIC STORAGE) | LIMITED BY ORBITER EXPENDABLES 30-60 DAYS                                              | LIMITED BY ORBITER EXPENDABLES DURATION DEPENDENT ON POWER LEVEL                | LIMITED BY PAYLOAD EXPENDABLES             |
| PAYLOAD POWER (EOL)          | 7 kW (3 kW FOR SPACELAB IF USED)                                                                                    | UP TO 15 kW (LESS 3 kW FOR SPACELAB)                                                                                 | 11 kW (3 kW FOR SPACELAB). FUNCTION OF ATTITUDE AND SOLAR BETA                         | 19 kW (3 kW FOR SPACELAB). 17-DAY MISSION. DEPENDENT ON ATTITUDE AND SOLAR BETA | 25 kW, FUNCTION OF ATTITUDE AND SOLAR BETA |
| P/L HEAT REJECTION           | 0.6 – 9.0 kWT + FLASH EVAPORATOR                                                                                    | 6.8 – 18.8 kWT + FLASH EVAPORATOR DEPENDENT ON BETA AND ATTITUDE                                                     | 9.7 – 26.3 kWT                                                                         |                                                                                 | 6.9-13.4 kWT + PALLET CAPABILITY           |
| ATTITUDES USABLE             | ANY ATTITUDE ACHIEVABLE. ATTITUDE HOLDING REQUIRES OPERATION OF ORBITER RCS/VCS WHICH INTERFERES WITH OBSERVATIONS. |                                                                                                                      | ANY ATTITUDE ACHIEVABLE. ATTITUDE HOLDING TIME DETERMINED BY PM CMG MOMENTUM BUILD UP. |                                                                                 |                                            |

\*ASSUMES MODIFICATION OF ORBITER SUBSYSTEMS TO PERMIT LONG DURATION MISSIONS.

#### MISSION ACCOMMODATION ANALYSIS APPROACH

- The chart outlines the analytical approach for evaluating mission accommodation capabilities.
- The logic flow of the analytical process is shown schematically on the next following chart.



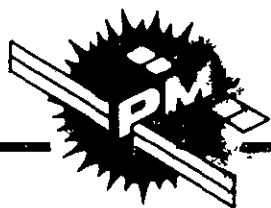
# MISSION ACCOMMODATION ANALYSIS APPROACH

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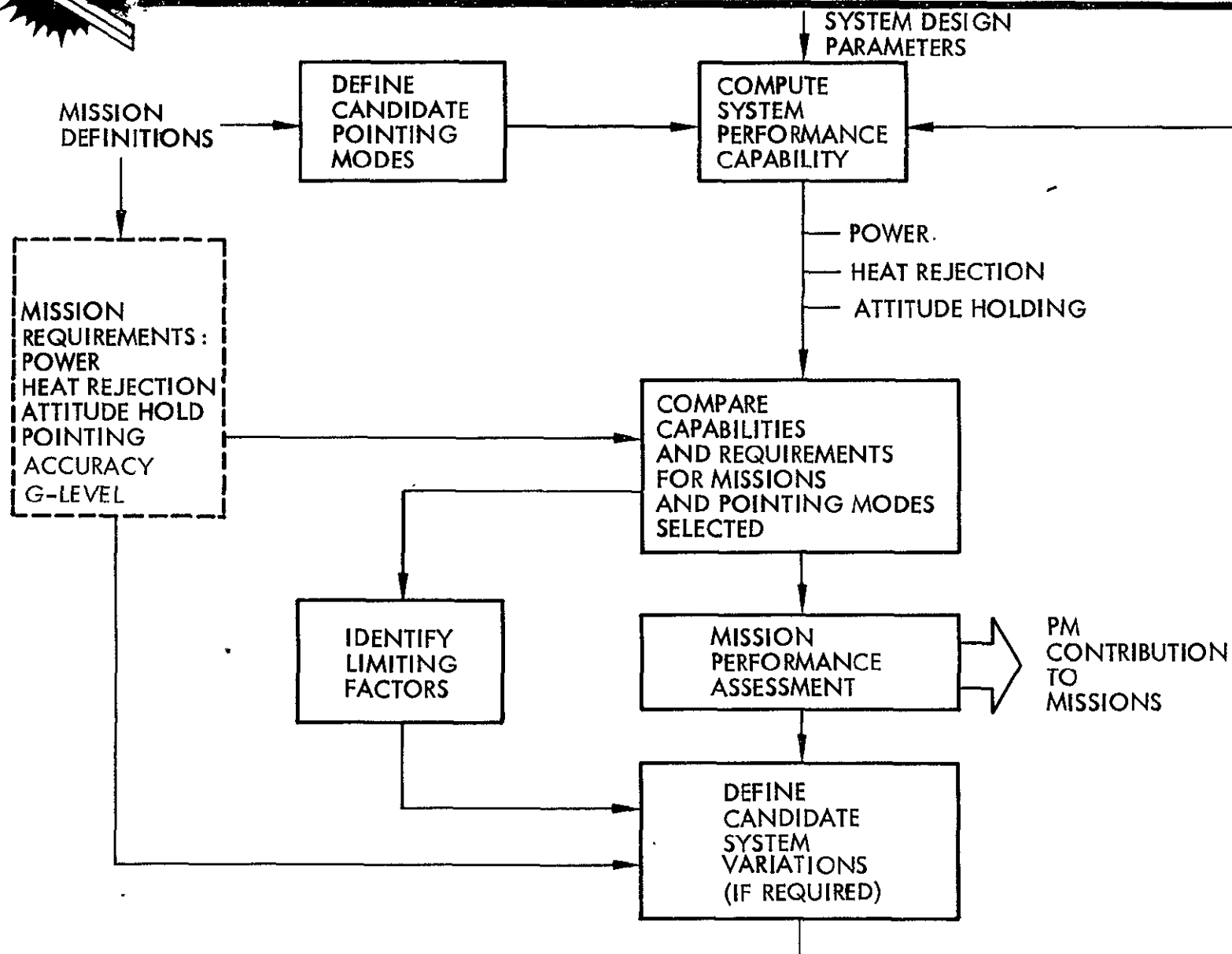
- MISSION CAPABILITY REQUIREMENTS:
  - VEHICLE TO OPERATE IN SUITABLE ATTITUDE
  - POWER GENERATION
  - REJECTION OF GENERATED HEAT
  - ATTITUDE HOLD COMPATIBLE WITH MEASUREMENT TIME
- SYSTEM PERFORMANCE DETERMINED BY ATTITUDE
- ANALYSIS PROCESS
  - DEFINE MISSION COMPATIBLE ATTITUDE MODES
  - COMPUTE ATTITUDE-RELATED SYSTEM PARAMETERS
  - EVALUATE SUBSYSTEM PERFORMANCE
  - ASSESS SYSTEM CAPABILITY
  - EVALUATE MISSION PERFORMANCE CAPABILITY
  - ASSESS CONTRIBUTION OF POWER MODULE TO MISSION CAPABILITY

## ANALYSIS PROCESS

- The analysis logic-flow is shown schematically. Input data came from the Part 1 effort, which provided information on the missions to be supported, and from Part 2 which provided system design characteristics.
- A series of pointing mode candidates (which determine both system performance and mission capabilities) were defined and the performance of the vehicle (minimum PM and design variations) in these modes was determined, both in sortie and free-flyer missions.
- Those attitude modes which yielded vehicle performance compatible with mission requirements were tested against the missions to determine their ability to conduct the required observations.
- This process was conducted iteratively, to reflect the fact that variations in vehicle design allow the use of attitude modes which permit more effective mission operations.

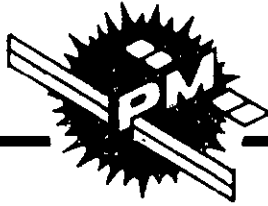


# ANALYSIS PROCESS



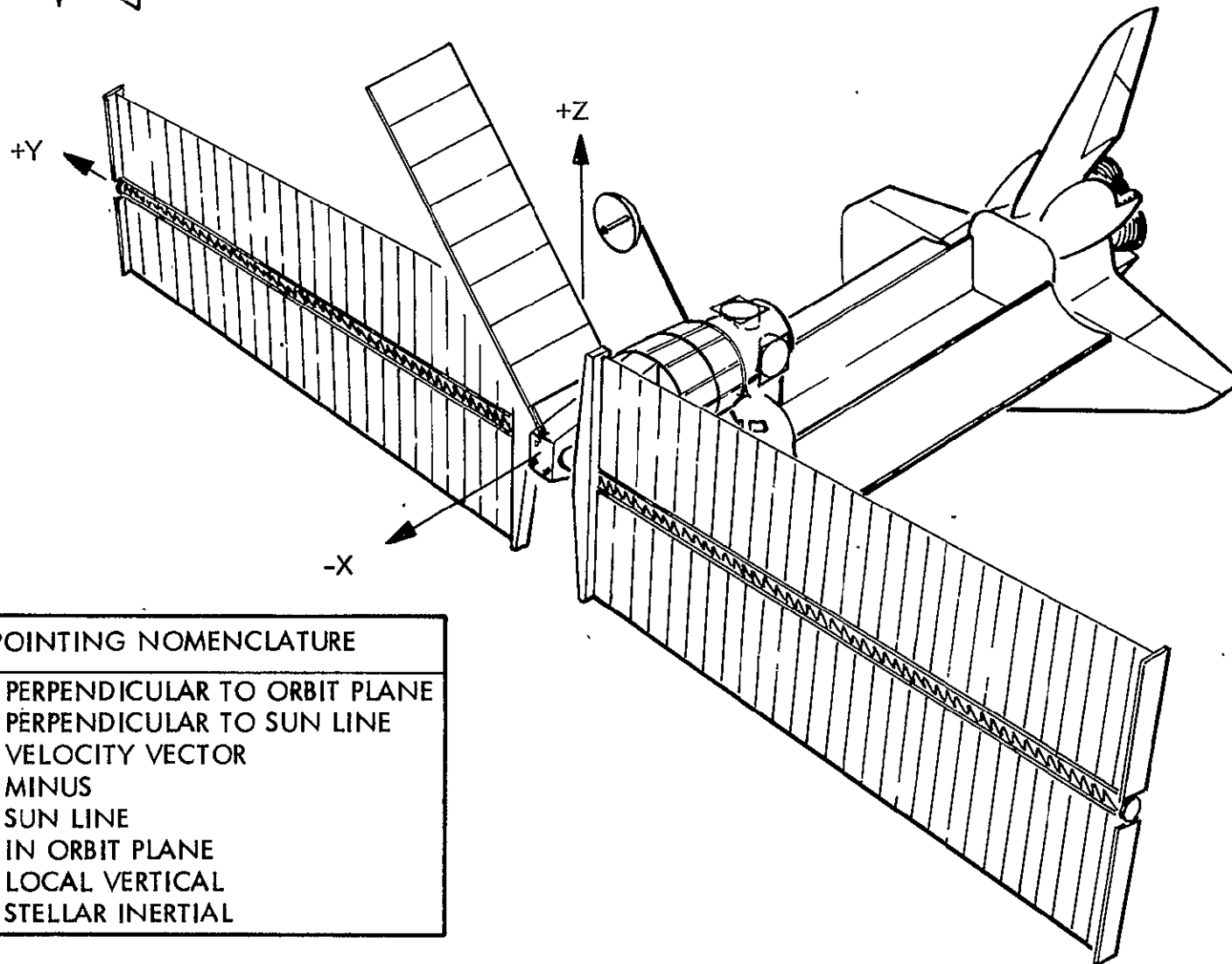
### VEHICLE AXES AND POINTING NOMENCLATURE

- This chart defines the vehicle axes and orientation abbreviations used in the analysis.



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## VEHICLE AXES AND POINTING NOMENCLATURE



### POINTING NOMENCLATURE

|     |                              |
|-----|------------------------------|
| POP | PERPENDICULAR TO ORBIT PLANE |
| PSL | PERPENDICULAR TO SUN LINE    |
| VV  | VELOCITY VECTOR              |
| M   | MINUS                        |
| SL  | SUN LINE                     |
| IOP | IN ORBIT PLANE               |
| LV  | LOCAL VERTICAL               |
| SI  | STELLAR INERTIAL             |

### ATTITUDE RELATED SYSTEM PARAMETERS

- Vehicle performance in each pointing mode is determined by ten angles, values of which are affected by the beta-angle and orbit inclination. The chart defines the angles and indicates their impacts on the system.
- These angles are prime inputs to the analysis of subsystem performance.





## ATTITUDE RELATED SYSTEM PARAMETERS

| <u>ANGLE</u>                     | <u>SIGNIFICANCE</u>                                                                                               |
|----------------------------------|-------------------------------------------------------------------------------------------------------------------|
| SUN – VEHICLE X AXIS             | THERMAL PERFORMANCE                                                                                               |
| SUN – VEHICLE Y AXIS             | POWER GENERATION, THERMAL PERFORMANCE                                                                             |
| SUN – VEHICLE Z AXIS             | THERMAL PERFORMANCE                                                                                               |
| NADIR – VEHICLE X AXIS           | CYCLICAL TORQUES-SHORT TERM<br>MOMENTUM BUILDUP, INERTIAL<br>ATTITUDES; BIAS TORQUES, EARTH<br>ORIENTED ATTITUDES |
| NADIR – VEHICLE Z AXIS           |                                                                                                                   |
| VELOCITY VECTOR – VEHICLE X AXIS | DRAG FORCES, ORBIT LIFE                                                                                           |
| VELOCITY VECTOR – VEHICLE Z AXIS |                                                                                                                   |
| ORBIT POLE – VEHICLE X AXIS      | BIAS TORQUES – LONG TERM<br>ATTITUDE HOLD                                                                         |
| ORBIT POLE – VEHICLE Y AXIS      |                                                                                                                   |
| EARTH NORTH – VEHICLE Z AXIS     | MAGNETIC MEASUREMENT<br>ENVIRONMENT                                                                               |

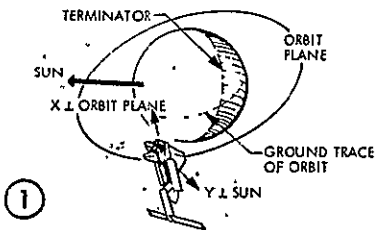
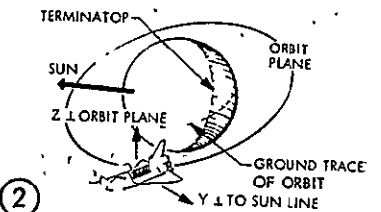
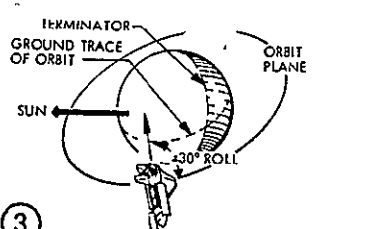
## POINTING MODES SELECTED FOR ANALYSIS (1 OF 4)

- After a review of previous work and available mission data, twelve pointing modes were designated as candidates for performance analysis. These were defined on the assumption that, in sortie missions, the payloads would be mounted in and would view from the orbiter bay. These four charts define, pictorially represent, and present a preliminary assessment of the characteristics and utility of each candidate mode.
- For each of these attitudes, vehicle capabilities (power to payload, heat rejection, and attitude holding) were computed. These data were developed for sortie and free flyer conditions for the minimum vehicle and for relevant variations. Applicable data are shown in the sections on the missions.



# POINTING MODES SELECTED FOR ANALYSIS (1 OF 4)

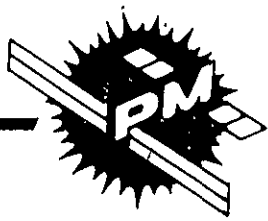
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| MODES                                                                                                                                                | EXPECTED CHARACTERISTICS                                                                                                                       | CANDIDATE MISSION APPLICATIONS                                                                                                                                                                                       |
|------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>XPOP, YPSL</b></p>  <p>①</p>                                  | <ul style="list-style-type: none"> <li>● FULL POWER</li> <li>● MINIMUM TORQUE</li> <li>● REDUCED H.R. AT LOW <math>\beta</math></li> </ul>     | <ul style="list-style-type: none"> <li>● CELESTIAL VIEWING AWAY FROM SUN</li> <li>● CELESTIAL VIEWING TOWARD SUN – SMALL BETA (IPS/SIPS REQUIRED)</li> <li>● MATERIAL PROCESSING</li> <li>● LIFE SCIENCE</li> </ul>  |
| <p><b>ZPOP, YPSL</b></p>  <p>②</p>                                  | <ul style="list-style-type: none"> <li>● FULL POWER</li> <li>● CYCLICAL TORQUES</li> <li>● REDUCED H.R. AT HIGH <math>\beta</math></li> </ul>  | <ul style="list-style-type: none"> <li>● CELESTIAL VIEWING NEAR ORBIT POLE (IPS/SIPS REQUIRED)</li> <li>● MAGNETIC MEASUREMENTS AT LOW INCLINATION</li> <li>● MATERIAL PROCESSING</li> <li>● LIFE SCIENCE</li> </ul> |
| <p><b>XPOP, YPSL <math>\pm 30^\circ</math> ROLL</b></p>  <p>③</p> | <ul style="list-style-type: none"> <li>● REDUCED POWER</li> <li>● MINIMUM TORQUES</li> <li>● REDUCED H.R. AT LOW <math>\beta</math></li> </ul> | <ul style="list-style-type: none"> <li>● CELESTIAL VIEWING</li> <li>● NADIR/LIMB OBSERVATION</li> <li>● MATERIAL PROCESSING</li> </ul>                                                                               |

## NOMENCLATURE:

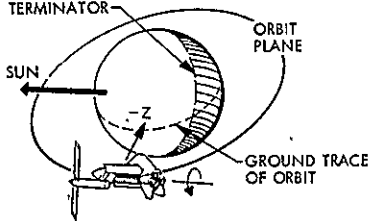
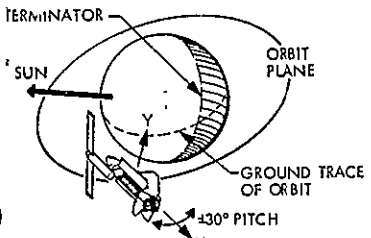
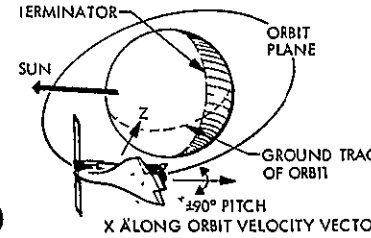
HR = HEAT REJECTION  
IPS = INSTRUMENT POINTING SYSTEM  
SIPS = SMALL IPS

XPOP = X AXIS PERPENDICULAR TO ORBIT PLANE  
YPSL = Y AXIS PERPENDICULAR TO SUN LINE



# POINTING MODES SELECTED FOR ANALYSIS (2 OF 4)

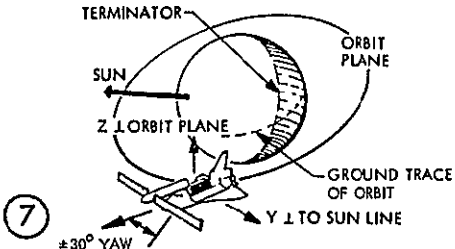
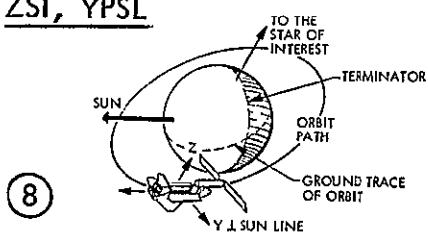
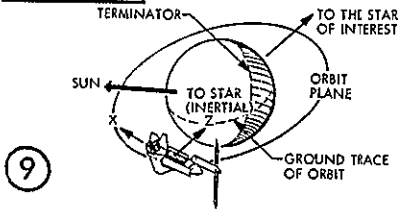
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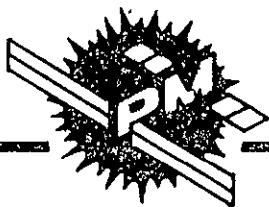
| MODES                                                                                                                                               | EXPECTED CHARACTERISTICS                                                                                                                                                                                                                                                                             | CANDIDATE MISSION APPLICATIONS                                                                                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <p><u>XVV, MZLV <math>\pm 30^\circ</math> ROLL</u></p> <p>④</p>    | <ul style="list-style-type: none"> <li>● REDUCED POWER AT HIGH <math>\beta</math></li> <li>● MIN TORQUE</li> <li>● CYCLICAL H.R. CAPABILITY</li> </ul>                                                                                                                                               | <ul style="list-style-type: none"> <li>● CELESTIAL VIEWING NEAR ORBIT PLANE</li> </ul>                            |
| <p><u>XIOP, ZSL <math>\pm 30^\circ</math> PITCH</u></p> <p>⑤</p>  | <ul style="list-style-type: none"> <li>● FULL POWER</li> <li>● CYCLICAL TORQUES</li> <li>● SECULAR TORQUES IF PITCH AND <math>\beta \neq 0</math></li> <li>● REDUCED H.R.</li> </ul>                                                                                                                 | <ul style="list-style-type: none"> <li>● SOLAR VIEWING</li> </ul>                                                 |
| <p><u>XVV, ZLV <math>\pm 90^\circ</math> PITCH</u></p> <p>⑥</p>  | <ul style="list-style-type: none"> <li>● REDUCED POWER AT HIGH <math>\beta</math></li> <li>● MIN DISTURBING TORQUE IF NOT PITCHED</li> <li>● SECULAR DISTURBING TORQUE IF PITCHED</li> <li>● IMPAIRED H.R.:<br/>CYCLICAL AT LOW <math>\beta</math><br/>REDUCED AT HIGH <math>\beta</math></li> </ul> | <ul style="list-style-type: none"> <li>● NADIR/LIMB VIEWING ALONG ORBIT TRACE</li> <li>● SOLAR VIEWING</li> </ul> |



# POINTING MODES SELECTED FOR ANALYSIS (3 OF 4)

LMSC-D614944-5

| MODES                                                                                                                                             | EXPECTED CHARACTERISTICS                                                                                                                                                             | CANDIDATE MISSION APPLICATIONS                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| <p><b>ZPOP, YPSL <math>\pm 30^\circ</math> YAW</b></p>  <p>⑦</p> | <ul style="list-style-type: none"> <li>● REDUCED POWER</li> <li>● CYCLICAL TORQUES</li> <li>● SECULAR TORQUE IF YAW AND <math>\beta \neq 0</math></li> <li>● REDUCED H.R.</li> </ul> | <ul style="list-style-type: none"> <li>● CELESTIAL VIEWING NEAR SUN</li> </ul> |
| <p><b>ZSI, YPSL</b></p>  <p>⑧</p>                               | <ul style="list-style-type: none"> <li>● FULL POWER</li> <li>● SECULAR AND CYCLICAL TORQUES</li> <li>● REDUCED H.R. (WHEN SUN TO STAR)</li> </ul>                                    | <ul style="list-style-type: none"> <li>● CELESTIAL VIEWING</li> </ul>          |
| <p><b>ZSI, XIOP</b></p>  <p>⑨</p>                              | <ul style="list-style-type: none"> <li>● REDUCED POWER</li> <li>● CYCLICAL TORQUES</li> <li>● REDUCED H.R.</li> </ul>                                                                | <ul style="list-style-type: none"> <li>● CELESTIAL VIEWING</li> </ul>          |



# POINTING MODES SELECTED FOR ANALYSIS (4 OF 4)

LMSC-D614944-5

| MODES                                                           | CHARACTERISTICS                                                                                                                                                          | CANDIDATE MISSION APPLICATIONS                                                                                                                             |
|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><u>ZLV, YPSL</u></p> <p>⑩</p>                                | <ul style="list-style-type: none"> <li>• FULL POWER</li> <li>• MIN TORQUE (BUT MANEUVERS REQUIRED)</li> <li>• REDUCED H.R. AT LOW-MID <math>\beta</math></li> </ul>      | <ul style="list-style-type: none"> <li>• NADIR VIEWING</li> </ul>                                                                                          |
| <p><u>XPOP, ZLV <math>\pm 90^\circ</math> ROLL</u></p> <p>⑪</p> | <ul style="list-style-type: none"> <li>• REDUCED POWER AT LOW <math>\beta</math></li> <li>• MINIMUM TORQUE</li> <li>• REDUCED H.R. AT HIGH <math>\beta</math></li> </ul> | <ul style="list-style-type: none"> <li>• NADIR/LIMB OBSERVATION</li> <li>• MATERIAL PROCESSING</li> <li>• LIFE SCIENCE</li> <li>• SOLAR VIEWING</li> </ul> |
| <p><u>YVV, XLV</u></p> <p>⑫</p>                                 | <ul style="list-style-type: none"> <li>• REDUCED POWER AT LOW <math>\beta</math></li> <li>• MINIMUM GRAVITY GRADIENT TORQUE</li> </ul>                                   | <ul style="list-style-type: none"> <li>• MATERIAL PROCESSING</li> <li>• LIFE SCIENCE</li> </ul>                                                            |

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### 3.2 POWER MODULE CHARACTERISTICS

#### POWER MODULE CHARACTERISTICS FOR ACCOMMODATIONS ANALYSIS

- The left hand column on the chart summarizes the mission related design parameters of the power module used as the point of departure in the analysis. It is essentially equivalent to the MSFC Phase A baseline.
- The right hand column defines excursions considered in the accommodations effort. Where, as in the thermal area, it was found that no variations were necessary, none were considered.
- The minimum vehicle defined here is functionally similar to the LMSC final configuration described in Volume I, Section 4. Physical differences between designs do not affect the results of this study.



## POWER MODULE CHARACTERISTICS FOR ACCOMMODATIONS ANALYSIS

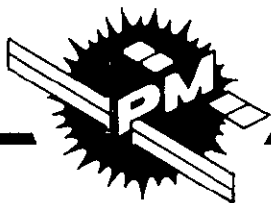
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|                     | <u>MINIMUM VEHICLE</u>                                                                                             | <u>VARIATIONS</u>                                         |
|---------------------|--------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| POWER<br>GENERATION | 25 kW AT 0 DEG $\beta$ IN 235 N. MI.<br>CIRCULAR ORBIT, SINGLE DEGREE OF<br>FREEDOM ARRAY                          | ROLL, YAW ROTATION OF ARRAY                               |
| HEAT<br>REJECTION   | 4 ORBITER RADIATOR PANELS                                                                                          |                                                           |
| ATTITUDE            | THREE CMGs (2300 FT-LB-SEC<br>CAPACITY EACH) DESATURATION<br>BY MANEUVER, ATM RATE GYROS,<br>NO PM ATTITUDE SENSOR | 4 - 6 CMGS<br>MAGNETIC DESATURATION<br>PM ATTITUDE SENSOR |
| C & DH              | ENGINEERING DATA HANDLING<br>MULTIPLE OMNI ANTENNAS                                                                | SCIENTIFIC DATA HANDLING<br>HIGH GAIN ANTENNAS            |



## STABILIZATION AND POINTING CAPABILITIES

- The ability of the Power Module to support free flyer missions will be determined by its ability to achieve and sustain attitudes compatible with the mission needs. This is, in turn, determined by the characteristics of the attitude control system.
- The minimum Power Module has CMGs for attitude control but no pointing sensors. Its capabilities are shown in the outlined area. It can be seen that this basic vehicle can fly in an earth oriented mode and can support Materials Processing and Life Sciences Missions. It is seen that support of precise pointing missions or operation in an inertial attitude requires addition of an attitude sensor.
- It can also be seen that any deletions from the minimum vehicle ACS would render it unable to support free-flyer missions.



## STABILIZATION & POINTING CAPABILITY

FREE-FLYER POWER MODULE WITH PALLETS IN-LINE

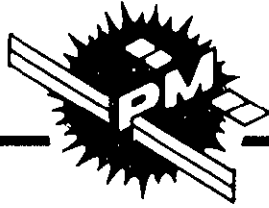
| <u>STABILIZATION</u>   | <u>POINTING</u>           | <u>PERFORMANCE</u>                                                                       | <u>MISSION ACCOMMODATION</u>                                                          | MINIMUM<br>VEHICLE<br>CAPABILITY |
|------------------------|---------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|----------------------------------|
| NONE                   | NONE                      | XLV, BUT LARGE<br>OSCILLATIONS. NO<br>CONTROL ABOUT X.                                   | NONE                                                                                  |                                  |
| CMG's                  | NONE                      | XLV. 3 TO 4 DEGREE<br>OSCILLATIONS.                                                      | NONE                                                                                  |                                  |
| RATE GYROS<br>AND CMGs | NONE                      | ANY PRINCIPAL AXIS LV.<br>CONTROL ABOUT LV BY<br>GYROCOMPASSING.                         | MATERIAL PROCESSING<br>AND LIFE SCIENCES                                              |                                  |
| RATE GYROS<br>AND CMGs | SUN SENSOR                | ANY PRINCIPAL AXIS LV.<br>CONTROL ABOUT LV BY<br>GYROCOMPASSING.<br>1/2 DEGREE POINTING. | MATERIAL PROCESSING AND<br>LIFE SCIENCES. STO AND<br>STELLAR (WITH POINTING<br>MOUNT) |                                  |
| RATE GYROS<br>AND CMGs | SUN SENSOR<br>STAR SENSOR | XPOP, INERTIAL, OR ANY<br>PRINCIPAL AXIS LV. 1 ARC<br>MINUTE POINTING.                   | MATERIAL PROCESSING AND<br>LIFE SCIENCES. STO AND<br>STELLAR (WITH POINTING<br>MOUNT) |                                  |

### 3.3 MISSION ACCOMMODATION ASSESSMENTS

#### 3.3.1 Solar Terrestrial Observation (STO)

##### STO MISSION REQUIREMENTS OVERVIEW

- The solar terrestrial observatory is an integrated set of instruments for the study of a variety of solar, terrestrial, and geomagnetic phenomenology.
- The instrument complement and arrangement were reviewed in detail during Part I of the Power Module Evolution Study.
- The mission requirements shown here are based on the Part I data supplemented by a consideration of potential STO observation programs by the LMSC Palo Alto Research Laboratory.



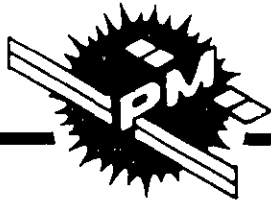
## STO MISSION REQUIREMENTS OVERVIEW

---

|                        |                                                                                                                                                                                                                  |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MISSION OBJECTIVE:     | INVESTIGATION OF SOLAR, TERRESTRIAL,<br>AND GEOMAGNETIC PHENOMENA<br>INDIVIDUALLY AND IN COMBINATION                                                                                                             |
| POWER REQUIREMENTS:    | 10-20 kW                                                                                                                                                                                                         |
| ATTITUDE REQUIREMENTS: | PAYLOAD INSTRUMENTS TO VIEW SUN,<br>EARTH, NADIR, ZENITH AND ALIGNED<br>WITH MAGNETIC FIELD LINES. VIEWING<br>MAY BE IN SINGLE DIRECTIONS OR IN<br>SIMULTANEOUS COMBINATIONS. SOME<br>INSTRUMENTS ARE GIMBALLED. |
| POINTING ACCURACY:     | INSTRUMENTS REQUIRE MINUTES OF ARC.<br>GIMBALS CAN ACCOMMODATE ORBITER<br>PERFORMANCE.                                                                                                                           |
| POINTING STABILITY:    | MINUTES OF ARC                                                                                                                                                                                                   |
| POINTING DURATION:     | SECONDS TO DAYS                                                                                                                                                                                                  |

## STO ACCOMMODATION ANALYSIS PROCESS

- The Solar-Terrestrial Observatory is a facility including a complement of instruments intended to permit investigations of a variety of phenomena. The work of Part 1 provided preliminary data on the incorporation of these instruments into shuttle payload bay pallets, pallets to be docked to the power module, and a package to be carried on the solar array support structure.
- The data available permitted the definition of the viewing capability, relative to the vehicle, of the various instrument packages.
- Based on a preliminary screening, five attitude modes were selected and the movements, during an orbit, of the targets considered to be of interest to STO investigators were computed. This permitted assessing the viewing capabilities afforded the experimenter in each mode.
- These data could then be merged to permit an overall assessment of the capability of each vehicle variation to perform the desired observations.



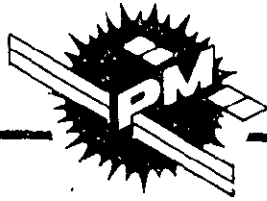
## STO ACCOMMODATION ANALYSIS PROCESS

---

- DEFINE PAYLOAD ELEMENTS (STO INCREMENTS 1 & 2)
- DEFINE PAYLOAD ARRANGEMENTS AND VIEWING CAPABILITY  
BASED ON FOV, BLOCKAGE AND GIMBAL LIMITS (SORTIE & FREE FLYER)
- DEFINE CANDIDATE ATTITUDE MODES
- DETERMINE VIEWING OPPORTUNITIES IN EACH ATTITUDE MODE
  - INDIVIDUAL TARGETS
  - MULTIPLE SIMULTANEOUS OBSERVATIONS
- COMBINE VEHICLE AND VIEWING CAPABILITY DATA FOR  
OVERALL ASSESSMENT

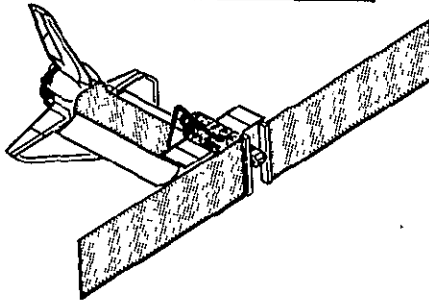
### PAYLOAD VIEWING CAPABILITIES ASSESSMENT

- The analysis process for assessing viewing capabilities is shown graphically on the chart.



# PAYLOAD VIEWING CAPABILITIES ASSESSMENT

## VEHICLE CONFIGURATION & PALLET ACCOMMODATIONS

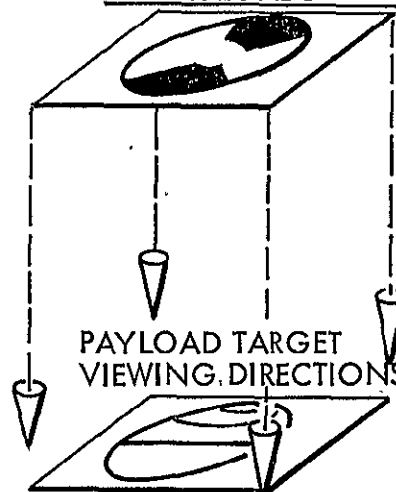


## PAYLOADS



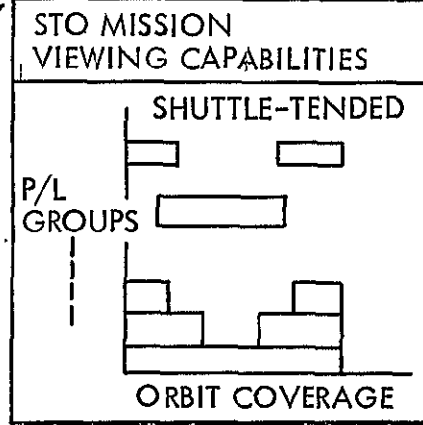
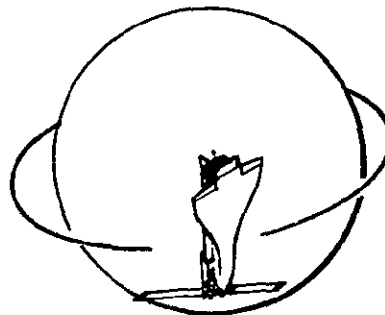
## GIMBAL SYSTEM

## MASK OF VIEWING CAPABILITY ANGLES OF PAYLOADS



PAYLOAD TARGET VIEWING DIRECTIONS

## VEHICLE ATTITUDE MODE



| STO VIEWING OPPORTUNITIES - MINUTES/REVOLUTIONS |  |  |  |  |  |
|-------------------------------------------------|--|--|--|--|--|
| ORIENTATIONS                                    |  |  |  |  |  |
| INCR NO 1 & 2                                   |  |  |  |  |  |

| STO VIEWING ASSESSMENT |  |  |  |  |  |
|------------------------|--|--|--|--|--|
| INCR NO 1 & 2          |  |  |  |  |  |

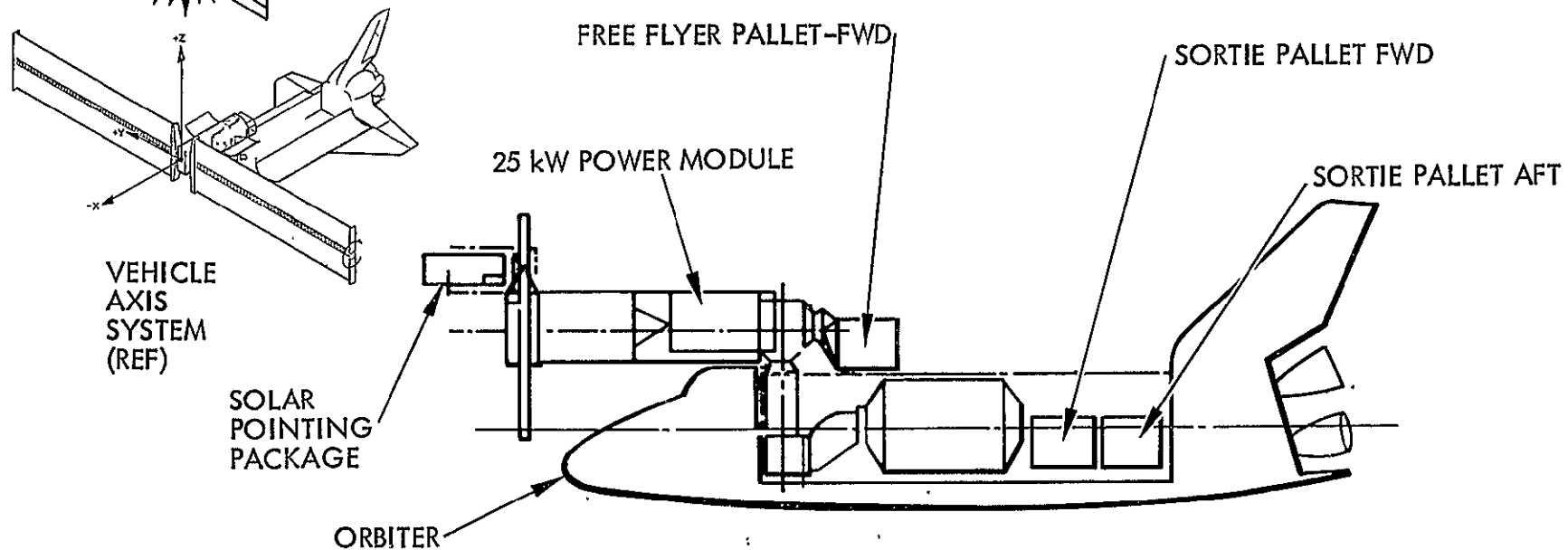


# STO SORTIE ARRANGEMENT - INCREMENT NO. 1

- The general arrangement of STO increment 1, as derived from Part 1 study, is shown here. It consists of a solar pointing package, one pallet to be docked to the power module and operated as a free-flyer, and two sortie pallets.
- It will be noted that, in the free-flyer mode, the power capability of the power module is adequate to permit all STO equipment to operate simultaneously (even though it is doubtful that an experiment would require such operation). However, in a sortie with SPACELAB, such operation would represent an overload. Therefore, an experiment time-line and power profile would be needed to define power requirements.



# STO SORTIE ARRANGEMENT-INCR NO.1



|                | PWR (kW)     |              |
|----------------|--------------|--------------|
|                | SORTIE       | FREE FLYER   |
| SPP            | 0.78         | 0.78         |
| FF/F PALLET    | 4.6          | 4.6          |
| SORTIE PALLETS | 0.97         |              |
| MISSION EQT    | 3.2          | 4.2          |
|                | <u>9.55*</u> | <u>9.48*</u> |

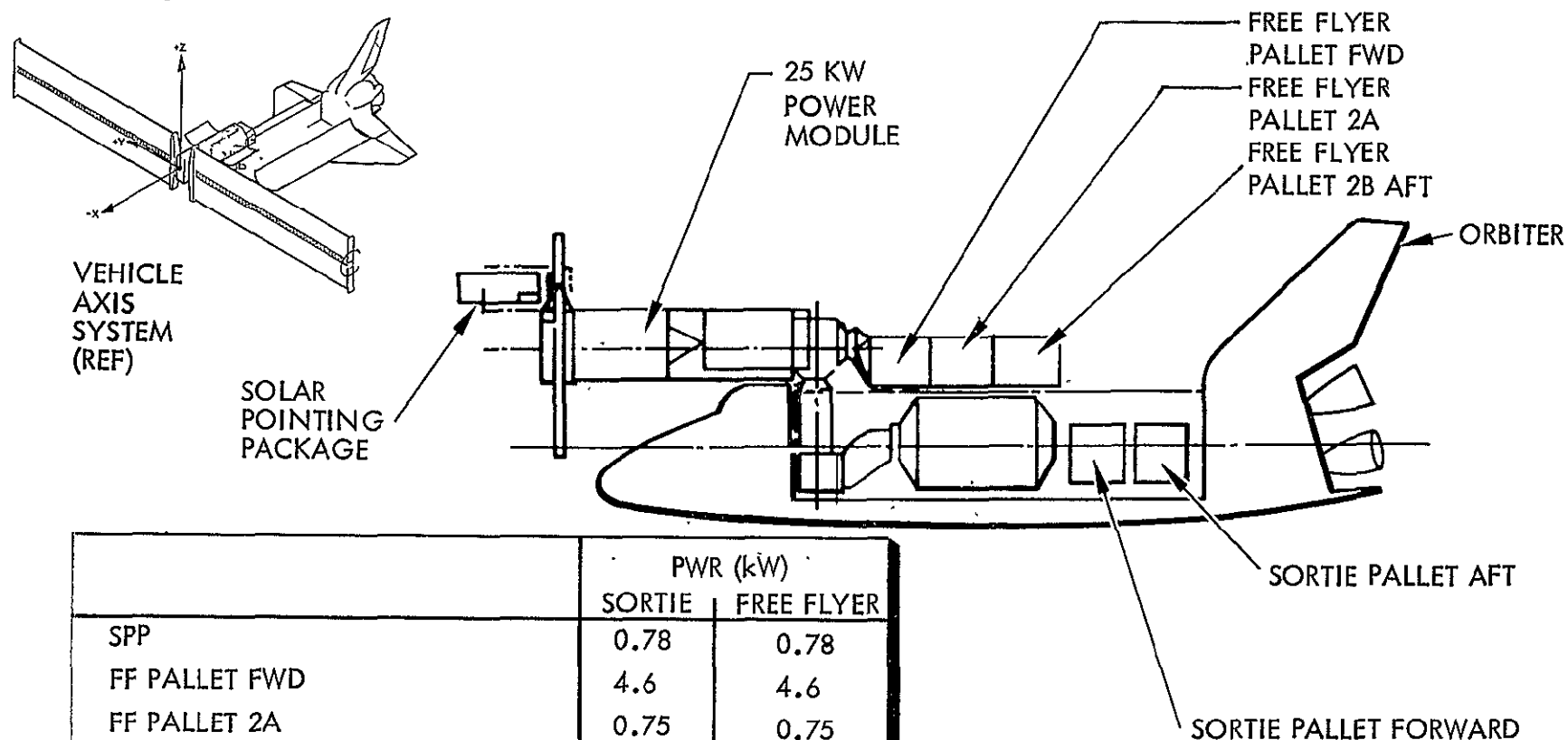
\*POWER DEMAND IF ALL EQUIPMENT WERE TO OPERATE SIMULTANEOUSLY

STO SORTIE ARRANGEMENT-INCREMENT NO. 2

- STO increment 2 adds two additional free-flyer pallets and represents changes in instrument complement.
- As for increment 1, power module power is adequate for operation of all apparatus as a free-flyer but power profiling is required to define experiment requirements in the sortie mode.



## STO SORTIE ARRANGEMENT-INCR NO.2

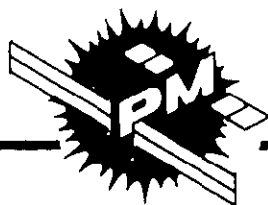


|                  | PWR (kW) |            |
|------------------|----------|------------|
|                  | SORTIE   | FREE FLYER |
| SPP              | 0.78     | 0.78       |
| FF PALLET FWD    | 4.6      | 4.6        |
| FF PALLET 2A     | 0.75     | 0.75       |
| FF PALLET 2B AFT | 8.0      | 8.0        |
| SORTIE PALLETS   | 1.11     |            |
| MISSION EQT      | 4.0      | 4.0        |
|                  | 19.2*    | 18.13*     |

\*POWER DEMAND IF ALL EQUIPMENT WERE TO OPERATE SIMULTANEOUSLY

PAYLOAD GROUPING FOR VIEWING  
ASSESSMENT-INCREMENT NO. 1

- This chart and the following chart describe the combinations of instruments and locations for viewing the various targets of interest to STO.
- This representative geometric information constitutes input data for the viewing capability analysis.



# PAYLOAD GROUPING FOR VIEWING ASSESSMENT

INCREMENT NO. 1

| PAYLOAD GROUP               | PALLET GROUP/POSITION | PAYLOAD DESIGNATOR: ST- |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  | VIEWING LIMITATIONS |                                                                                                                                                                                              |
|-----------------------------|-----------------------|-------------------------|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|--|--|--|--|--|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                             |                       | 1-6                     | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |  |  |  |  |  |  |                     |                                                                                                                                                                                              |
| <u>SUN</u>                  |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |                     | GIMBAL LIMITS: ±100° IN PITCH, ±60° IN YAW<br>VEHICLE BLOCKAGE                                                                                                                               |
| SOLAR POINTING PACKAGE      | SPP                   | X                       |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |                     |                                                                                                                                                                                              |
| SOLAR PHYSICS               | S/F                   |                         |   |   |   |    |    |    |    |    |    |    |    | X  | X  |    |    |    | X  |  |  |  |  |  |  |                     |                                                                                                                                                                                              |
| <u>EARTH VIEWING</u>        |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |                     | } ±60 GIMBAL LIMITS FORE & AFT<br>OTHERWISE, VEHICLE BLOCKAGE<br>DUE TO PALLET SIDES, POWER<br>MODULE, DOCKING ADAPTER<br>AND SOLAR ARRAYS<br><br>SAME AS NOTE BELOW FOR<br>"UPWARD VIEWING" |
| NADIR                       | FF/F                  |                         |   |   |   |    |    |    |    |    | X  |    |    |    |    |    |    |    |    |  |  |  |  |  |  |                     |                                                                                                                                                                                              |
| EARTH LIMB<br>(FORWARD/AFT) | FF/F                  |                         |   |   |   |    |    |    |    |    |    |    | X  | X  |    |    |    |    |    |  |  |  |  |  |  |                     |                                                                                                                                                                                              |
| MAGNETIC FIELD<br>LINES     | S/F + A<br>FF/F       |                         |   | X | X |    |    |    |    |    | X  |    |    |    |    |    | X  | X  |    |  |  |  |  |  |  |                     |                                                                                                                                                                                              |
| <u>UPWARD VIEWING</u>       |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |                     | VEHICLE BLOCKAGE<br>REFER TO "NADIR GROUP", COMMON INTERSECTION<br>BETWEEN FWD & 2A PALLETS FURTHER RESTRICTS VIEWING                                                                        |
| MAGNETIC<br>FIELD LINES     | S/F + A<br>FF/F       |                         |   | X | X |    |    |    |    |    | X  |    |    |    |    |    | X  | X  |    |  |  |  |  |  |  |                     |                                                                                                                                                                                              |

\*THIS PAYLOAD IS NOT AFFECTED BY USUAL VIEWING LIMITATIONS.

\*\*A SUBSATELLITE DEPLOYED BY RMS OR OTHER MEANS. NOTE \*APPLIES.

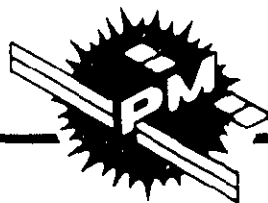
PALLET NOMENCLATURE: GROUP: SPP-SOLAR POINTING PACKAGE, S/ = SORTIE, FF/ = FREE FLYER

POSITION: /F = FORWARD, /A = AFT, /2A = MIDDLE, U = FOV COVERAGE IN EITHER PALLET

$\cap$  = SIMULTANEOUS COVERAGE

PAYLOAD GROUPING FOR VIEWING  
ASSESSMENT-INCREMENT NO. 2

- Refer to discussion with previous chart



# PAYLOAD GROUPING FOR VIEWING ASSESSMENT

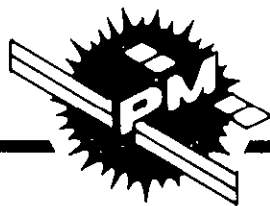
## INCREMENT NO. 2

| PAYLOAD GROUP                                                                                                                                                                                                                                                                                                                          | PALLET GROUP/POSITION | PAYLOAD DESIGNATOR: ST- |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  | VIEWING LIMITATIONS |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------------------------|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|---|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---------------------|
|                                                                                                                                                                                                                                                                                                                                        |                       | 1-6                     | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
| <u>SUN</u>                                                                                                                                                                                                                                                                                                                             |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
| SOLAR POINTING PACKAGE                                                                                                                                                                                                                                                                                                                 | SPP                   | X                       |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
| SOLAR PHYSICS                                                                                                                                                                                                                                                                                                                          | S/F<br>FF/2A          |                         | X |   |   | X  |    |    |    |    |    |    | X  | X  |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
|                                                                                                                                                                                                                                                                                                                                        |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   | GIMBAL LIMITS: ± 100° IN PITCH, ±60° IN YAW<br>VEHICLE BLOCKAGE                                                                                                                                                                                                           |  |                     |
| <u>EARTH VIEWING</u>                                                                                                                                                                                                                                                                                                                   |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
| NADIR                                                                                                                                                                                                                                                                                                                                  | FF/FU2A               |                         |   |   |   |    |    |    |    | X  |    |    |    |    |    |    |    |    |    |    |  |   | X |                                                                                                                                                                                                                                                                           |  |                     |
| EARTH LIMB (FORWARD/AFT)                                                                                                                                                                                                                                                                                                               | S/F<br>FF/FU2A        |                         |   |   |   |    |    |    |    |    |    | X  |    |    |    |    |    |    | X  |    |  | X | X |                                                                                                                                                                                                                                                                           |  |                     |
| MAGNETIC FIELD LINES                                                                                                                                                                                                                                                                                                                   | S/F + A<br>FF/F       |                         |   |   | X | X  |    |    |    |    | X  |    |    |    |    | X  | X  |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
|                                                                                                                                                                                                                                                                                                                                        |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   | ±60° GIMBAL LIMITS FORE & AFT<br>OTHERWISE, VEHICLE BLOCKAGE<br>DUE TO PALLET SIDES, POWER<br>MODULE, DOCKING ADAPTER<br>AND SOLAR ARRAYS<br><br>VEHICLE BLOCKAGE<br>REFER TO "NADIR GROUP". COMMON<br>INTERSECTION BETWEEN FWD & 2A PALLETS<br>FURTHER RESTRICTS VIEWING |  |                     |
| <u>UPWARD VIEWING</u>                                                                                                                                                                                                                                                                                                                  |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
| ZENITH                                                                                                                                                                                                                                                                                                                                 | FF/2A                 |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   | X |                                                                                                                                                                                                                                                                           |  |                     |
| MAGNETIC FIELD LINES                                                                                                                                                                                                                                                                                                                   | S/F + A<br>FF/F       |                         |   |   | X | X  |    |    |    |    | X  |    |    |    |    | X  | X  |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
|                                                                                                                                                                                                                                                                                                                                        |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   | SAME AS NOTE ABOVE FOR EARTH VIEWING                                                                                                                                                                                                                                      |  |                     |
|                                                                                                                                                                                                                                                                                                                                        |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |
| *THIS PAYLOAD IS NOT AFFECTED BY USUAL VIEWING LIMITATIONS<br>**A SUBSATELLITE DEPLOYED BY RMS OR OTHER MEANS. NOTE *APPLIES.<br>PALLET NOMENCLATURE: GROUP: SPP - SOLAR POINTING PACKAGE, S/ = SORTIE, FF/ = FREE FLYER<br>POSITION: /F = FORWARD, /A = AFT, /2A = MIDDLE, U = COVERAGE IN EITHER PALLET<br>U = SIMULTANEOUS COVERAGE |                       |                         |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |   |   |                                                                                                                                                                                                                                                                           |  |                     |



STO SOLAR POINTING PACKAGE  
INCREMENTS 1 AND 2

- This chart, together with the three following charts, identify the instruments assumed to be in several STO packages and provide an indication of their coverage and pointing capability. This chart lists those packages which are mounted forward on the solar array assembly.
- It can be seen that instruments with narrow fields of view are generally provided with pointing packages thus making the gimbal limits the effective viewing coverage of those instruments.



# STO SOLAR POINTING PACKAGE-INCR 1 & 2

LMSC-D614944-5

| <u>DESIG</u> | <u>INCR #</u> | <u>PAYLOADS</u>                       | <u>TYPE MOUNTING</u> | <u>TARGET DIRECTION</u> | <u>ASSUMED PAYLOAD FOV</u> |
|--------------|---------------|---------------------------------------|----------------------|-------------------------|----------------------------|
| ST-1         | 1 & 2         | SOLAR CONSTANT MONITOR                | COMMON<br>GIMBAL     | SUN                     | 8°                         |
| -2           | 1 & 2         | SOLAR SPECTRAL IRRADIANCE MEASUREMENT |                      |                         | 5°                         |
| -3           | 1 & 2         | SOFT X-RAY (SXR) TELESCOPE            |                      |                         | 0.5°                       |
| -4           | 1 & 2         | CORONAGRAPH/POLARIMETER               |                      |                         | 1.5°                       |
| -5           | 1 & 2         | OPTICAL TELESCOPE MAGNETOGRAPH        |                      |                         | 5M                         |
| -6           | 1 & 2         | HARD X-RAY FLARE DETECTOR             |                      |                         | ±45°                       |

STO SORTIE PALLETS – INCREMENTS 1 & 2

- Refer to discussions with previous chart.
- The chart lists the payloads carried on pallets configured for sortie operations, mounted in the Orbiter payload bay.



## STO SORTIE PALLETS-INCR 1 & 2

| <u>DESIG</u> | <u>INCR #</u> | <u>PAYLOADS</u>                                                                                                                                                                             | <u>TYPE MOUNTING</u> | <u>TARGET DIRECTION</u> | <u>ASSUMED PAYLOAD FOV</u> |
|--------------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-------------------------|----------------------------|
| -16          | 1 & 2         | SPECIAL PURPOSE SOLAR PHYSICS CLUSTER:<br>- DUAL WHITELIGHT CORONAGRAPH<br>- UV SCANNING POLY-SPECTROHELIOGRAPH<br>- X-RAY SPECTROMETER - SPECTROGRAPH - TELESCOPE<br>- H-ALPHA 1 TELESCOPE | } COMMON GIMBAL }    | } SUN }                 | 15° X 105° TO 1.5°         |
| -17          | 1 & 2         | XUV SPECTROMETER-HELIOGRAPH                                                                                                                                                                 |                      |                         | 0.75°                      |
| -18          | 1 & 2         | PLASMA DIAGNOSTIC PACKAGE (RMS HELD & SUBSATELLITE)                                                                                                                                         |                      |                         |                            |
| -19          | 1 & 2         | GAS/CHEMICAL RELEASE                                                                                                                                                                        |                      |                         |                            |
| -21          | 2             | MICROWAVE LIMB SCANNER                                                                                                                                                                      | GIMBAL               | LIMB                    | 4° X 4°                    |

STO FREE-FLYER PALLETS - INCREMENTS 1 & 2 (1 OF 2)

- Refer to discussions with two previous charts.
- This chart lists the payloads carried on pallets configured for Power Module free-flyer operations.

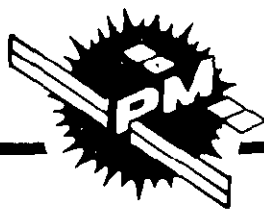


# STO FREE-FLYER PALLETS -INCR 1 & 2 (SH 1 OF 2)

| <u>DESIG</u> | <u>INCR #</u> | <u>PAYLOADS</u>                        | <u>TYPE MOUNTING</u> | <u>TARGET DIRECTION</u> | <u>ASSUMED PAYLOAD FOV</u> |
|--------------|---------------|----------------------------------------|----------------------|-------------------------|----------------------------|
| - 7          | 2             | SOLAR GAMMA RAY SPECTROMETER           | GIMBAL               |                         | 0.5°                       |
| - 8          | 1 & 2         | LOW LIGHT-LEVEL TV                     | GIMBAL               | VARIOUS                 | 20° OR 6°                  |
| - 9          | 1 & 2         | SEPAC (SPACE EXPR + PARTICLE ACCEL)    | FIXED                | ALONG MAGNETIC FIELD    | ±45°                       |
| -10          | 2             | XUV SOLAR WIND MONITOR                 | FIXED                | SUN                     | 3°-10°                     |
| -11          | 1 & 2         | X-RAY IMAGER                           | FIXED                | VARIOUS                 | 60°                        |
| -12          | 1 & 2         | LIDAR (LASER SOUNDER)                  | FIXED                | NADIR                   | 10°                        |
| -13          | N/A           |                                        |                      |                         |                            |
| -14          | 1 & 2         | IMAGING SPECTROMETER OBSERVATORY       | FIXED                | BASICALLY DOWN          | 0.007° X 0.5°              |
| -15          | 1 & 2         | ATMOSPHERIC TRACE MOLECULE             | GIMBAL               | LIMB                    | ±10°                       |
| -20          | 1             | HIGH RESOLUTION TELESCOPE SPECTROGRAPH | GIMBAL               | SUN                     | 0.5° X 900°                |

STO FREE-FLYER PALLETS - INCREMENTS 1 & 2 (2 OF 2)

- Refer to discussion with previous chart.



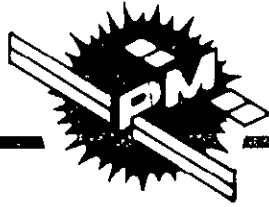
# STO FREE - FLYER PALLETS - INCR 1 & 2 (SH 2 OF 2)

| <u>DESIG</u> | <u>INCR #</u> | <u>PAYLOADS</u>                                                                                                                                             | <u>TYPE MOUNTING</u> | <u>TARGET DIRECTION</u> | <u>ASSUMED PAYLOAD FOV</u> |
|--------------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-------------------------|----------------------------|
| -22          | 2             | CRYO-LIMB INTERFEROMETER<br>RADIOMETER (CLIR)                                                                                                               | GIMBAL               | LIMB                    | 4° X 4°                    |
| -23          | 2             | FABRY-PEROT INTERFEROMETER                                                                                                                                  | GIMBAL               | ZENITH<br>LIMB<br>NADIR | 3°-4°                      |
| -24          | 2             | WAVE INJECTION FACILITY<br>- ENERGY/MOM. INSTRUMENT<br>- IONOSPHERE MOD. INSTRUMENT<br>(HF + X-BAND)<br>- VLF (1 Hz - 200 MHz) EXPERIMENT<br>- SUBSATELLITE | FIXED                | VARIOUS                 | 1°+                        |



### STO ANALYSIS GROUND RULES

- This chart sets out the assumptions underlying the STO viewing analysis. Essentially, because of the requirement for operating in both sortie and free flyer modes, the nominal (gimbal centered) pointing direction of pallet instruments is parallel to the vehicle Z-axis.



## STO ANALYSIS GROUNDRULES

---

- ALL PAYLOADS (EXCEPT SPP) NORMALLY LOOK IN +Z DIRECTION
- SOLAR POINTING PACKAGE (SPP) ELEVATION GIMBAL  $\phi$  INSTALLED ALONG X-ELEMENT (ROTATES IN NOSE-TO-TAIL PLANE)
- ELEVATION GIMBAL  $\phi$  FOR PALLET PAYLOADS INSTALLED ALONG Z-ELEMENT (ROTATES IN WING-TO-WING PLANE)
- 450 KM,  $57^\circ$  INCLINATION ORBIT
- VIEWING OPPORTUNITY DEFINED BY VEHICLE ATTITUDE, GIMBAL CONSTRAINT AND VEHICLE BLOCKAGE.

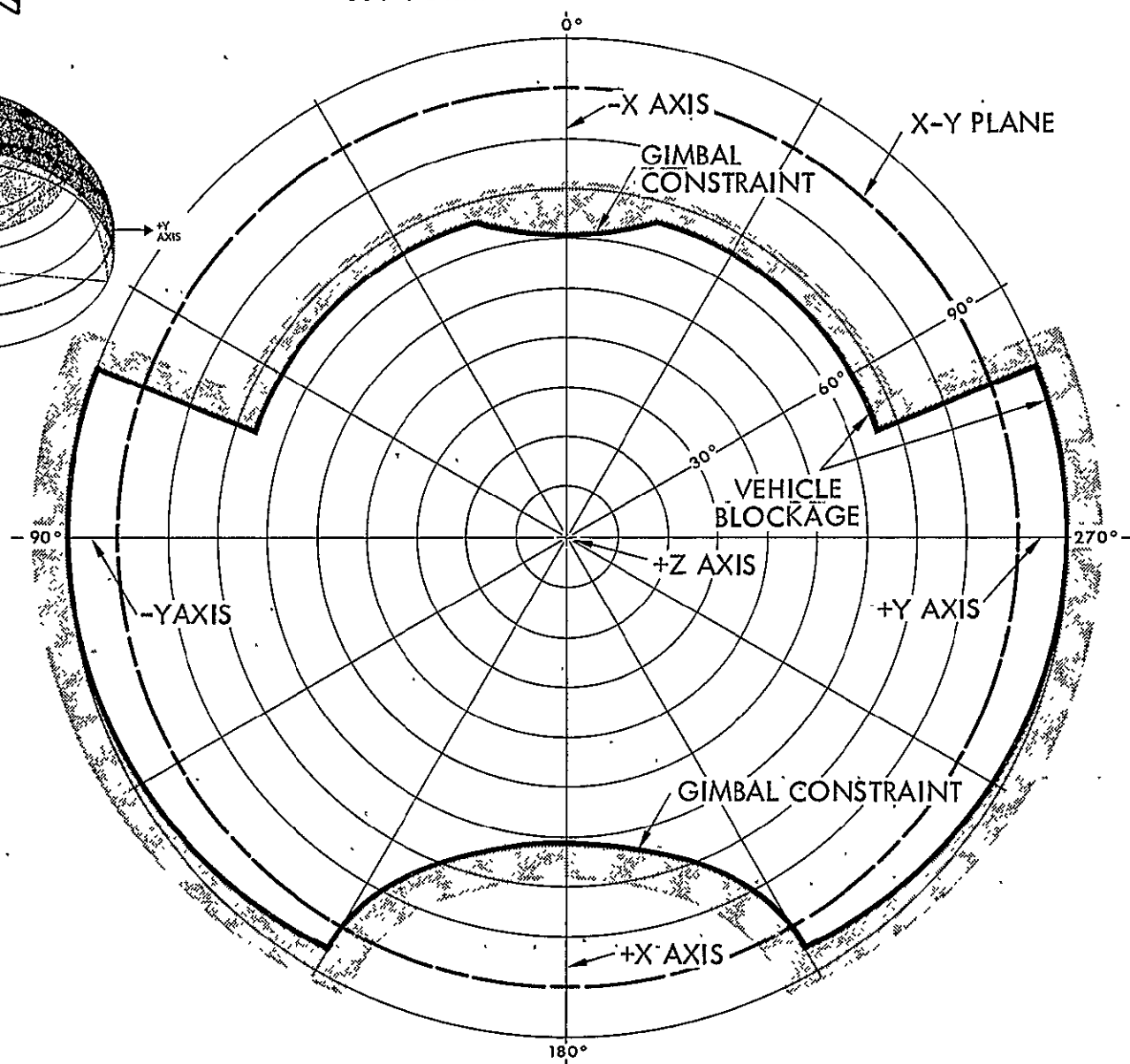
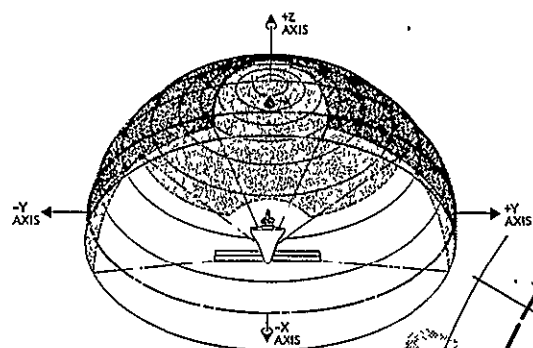
### VIEWING CAPABILITY ANGLE

- When vehicle blockage and gimbal limits are taken into account they define a viewing volume, relative to the vehicle. This is shown schematically and in the form of a coverage mask which will be used in the viewing computation process.
- The particular instrument set shown as an example is the free flyer forward pallet. Equivalent masks were generated for each instrument group and for logical combinations where appropriate.



# VIEWING CAPABILITY ANGLE

STO FORWARD FREE FLYER PALLET



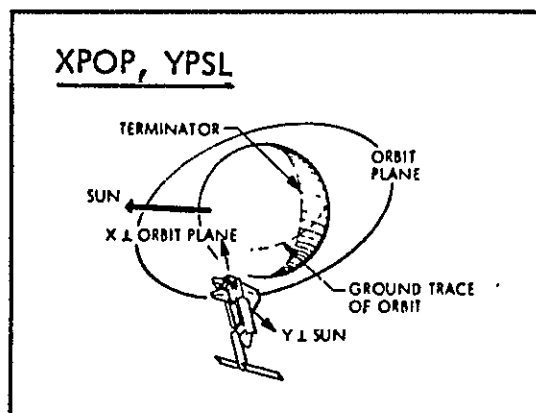
## ATTITUDE MODES CONSIDERED FOR STO

- The STO mission imposes severe pointing constraints in that it can require high power and simultaneous long term inertial (sun) and earth oriented viewing (nadir, limb, zenith, and magnetic field lines).
- The data from Part I yielded an STO instrument arrangement in which the power and sortie nominal (gimbal centered) instrument pointing directions are along the Z-axis (X-axis for the solar pointing package).
- Five representative attitude modes were selected for the initial viewing analyses on the basis that they provided high power, relatively low gravity gradient disturbing forces, and apparently favorable viewing potential:
  1. XPOP, YPSL (inertial) provides full solar array illumination and minimum gravity gradient disturbing forces. The angle between the sun and the Z-axis is equal to the beta-angle; sun/X-axis angle equals  $90 - \beta$ . This attitude is suitable for solar viewing. But, since the Z-axis is in the orbit plane with a fixed direction, as the satellite circles, the earth can be viewed for only a portion of the orbit.
  2. XPOP, YPSL (inertial) provides full solar array illumination and requires CMG momentum storage capability to absorb cyclical gravity gradient torques. Sun/Z-axis and sun/X-axis angles are  $90 - \beta$  and  $\beta$  respectively, which are favorable for solar viewing. Nadir Z-axis angle is  $90^\circ$ , permitting substantial earth viewing with gimbaled instruments.
  3. XLOP, ZSL (inertial) provides full solar array illumination and requires momentum storage and desaturation capability for bias and cyclical torques. The sun/Z-axis angle is zero for all values of beta; the sun/X-axis angle is  $90^\circ$ , permitting continuous solar viewing. The nadir/Z-axis angle oscillates between  $\beta$  and  $180 - \beta$ , permitting earth viewing for part of the orbit.
  4. XVV, ZLV (earth oriented) is stable and provides full solar power at low beta. Power, however, falls sharply for  $\beta$  above  $40^\circ$ . Continuous earth viewing is possible but only partial orbit solar-viewing.
  5. XPOP, ZLV (earth oriented) is stable and provides full solar power at high beta. Power is sharply reduced for  $\beta$  below  $40^\circ$ . Continuous earth viewing is possible and substantial solar viewing at high values of  $\beta$ .
- It should be emphasized that these are not suggested as the totality of available modes or even that these are necessarily the best operating modes. They are, however, representative and should provide a reasonable measure of mission capability.

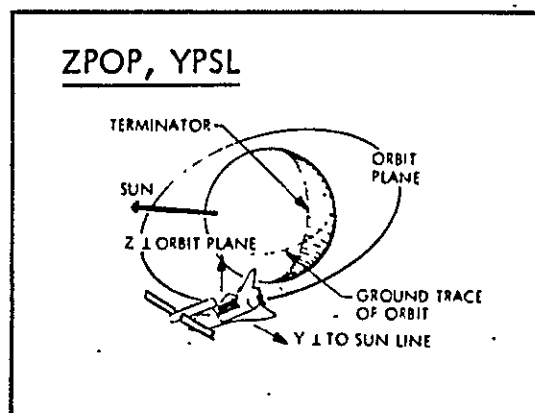


# ATTITUDE MODES CONSIDERED FOR STO

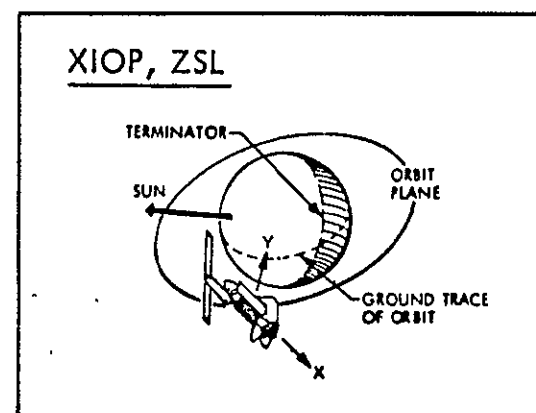
## INERTIAL ORIENTED



- 25 kW POWER
- 3 CMGs FOR LONG TERM HOLD

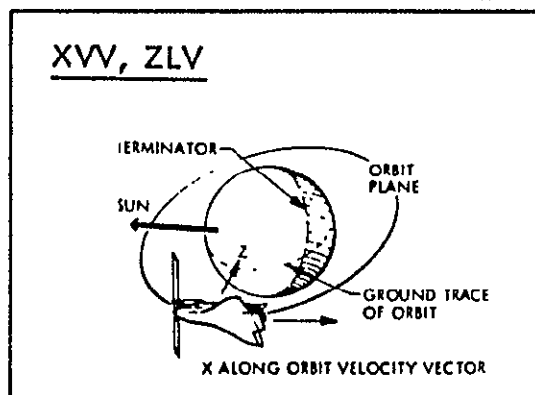


- 25 kW POWER
- 4 CMGs FOR LONG TERM HOLD (SORTIE MODE)

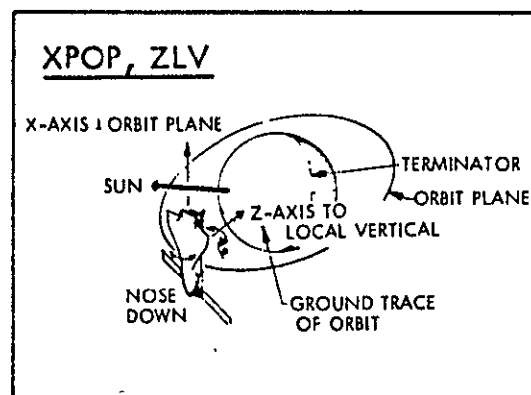


- 25 kW
- 5 CMGs (SORTIE-MODE) AND FOR LONG TERM HOLD

## EARTH ORIENTED



- LOW POWER AT HIGH  $\beta$
- 3 CMGs OK



- LOW POWER AT LOW  $\beta$
- 3 CMGs OK

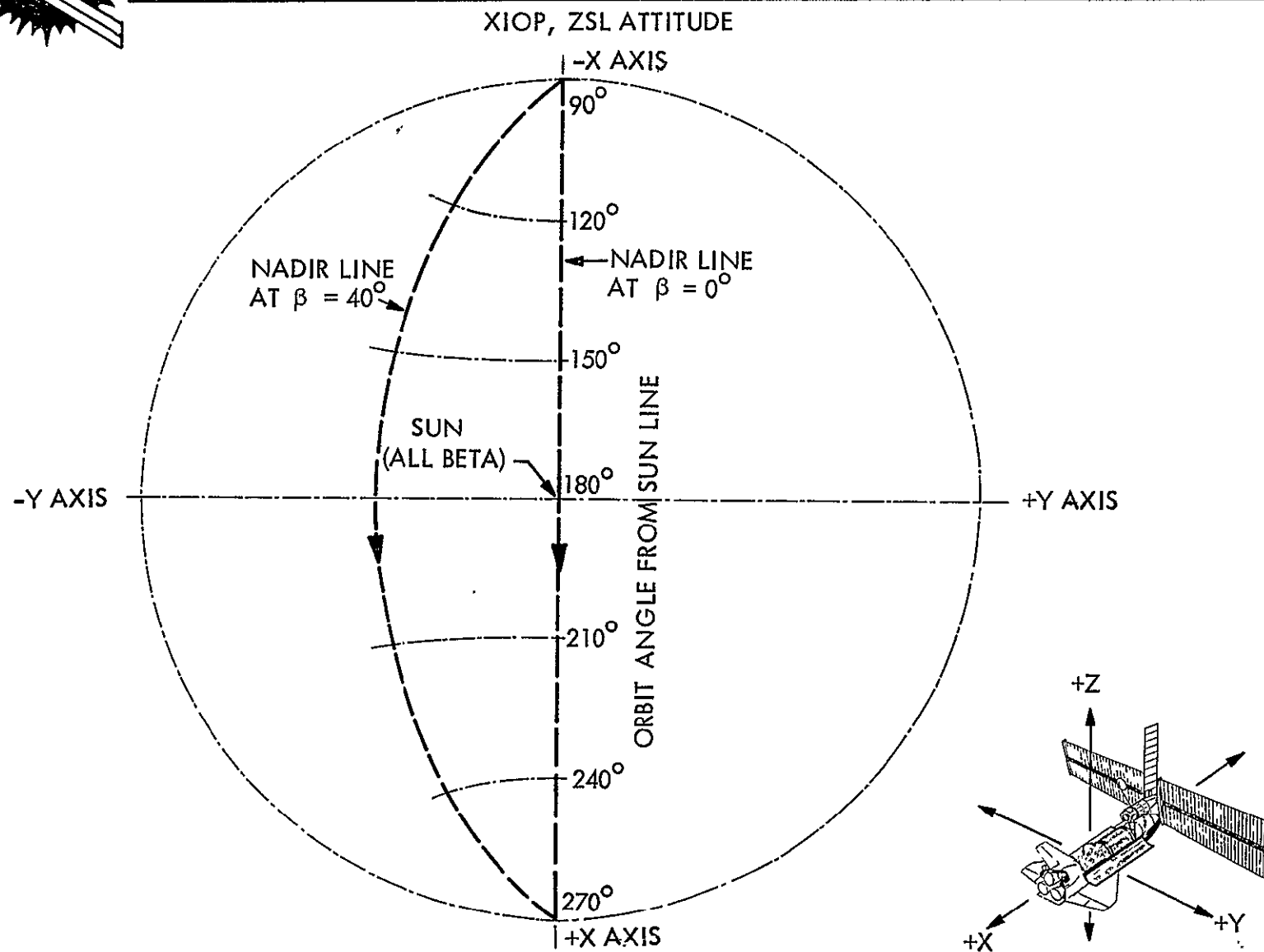
ORBITER THERMAL RESTRICTIONS TBD

## VIEWING CONDITIONS

- When an attitude mode is defined, it becomes possible to define the movement of each of the targets relative to the vehicle during a revolution. The target tracks will depend on the attitude mode and on the solar beta. In the sample shown here, the XIOP, ZSL attitude was chosen in which the sun is in the direction of the positive Z axis. The picture shows the movement, in the instrument pointing space, of the Nadir for the case of zero beta and for a beta of 40 degrees.



# VIEWING CONDITIONS





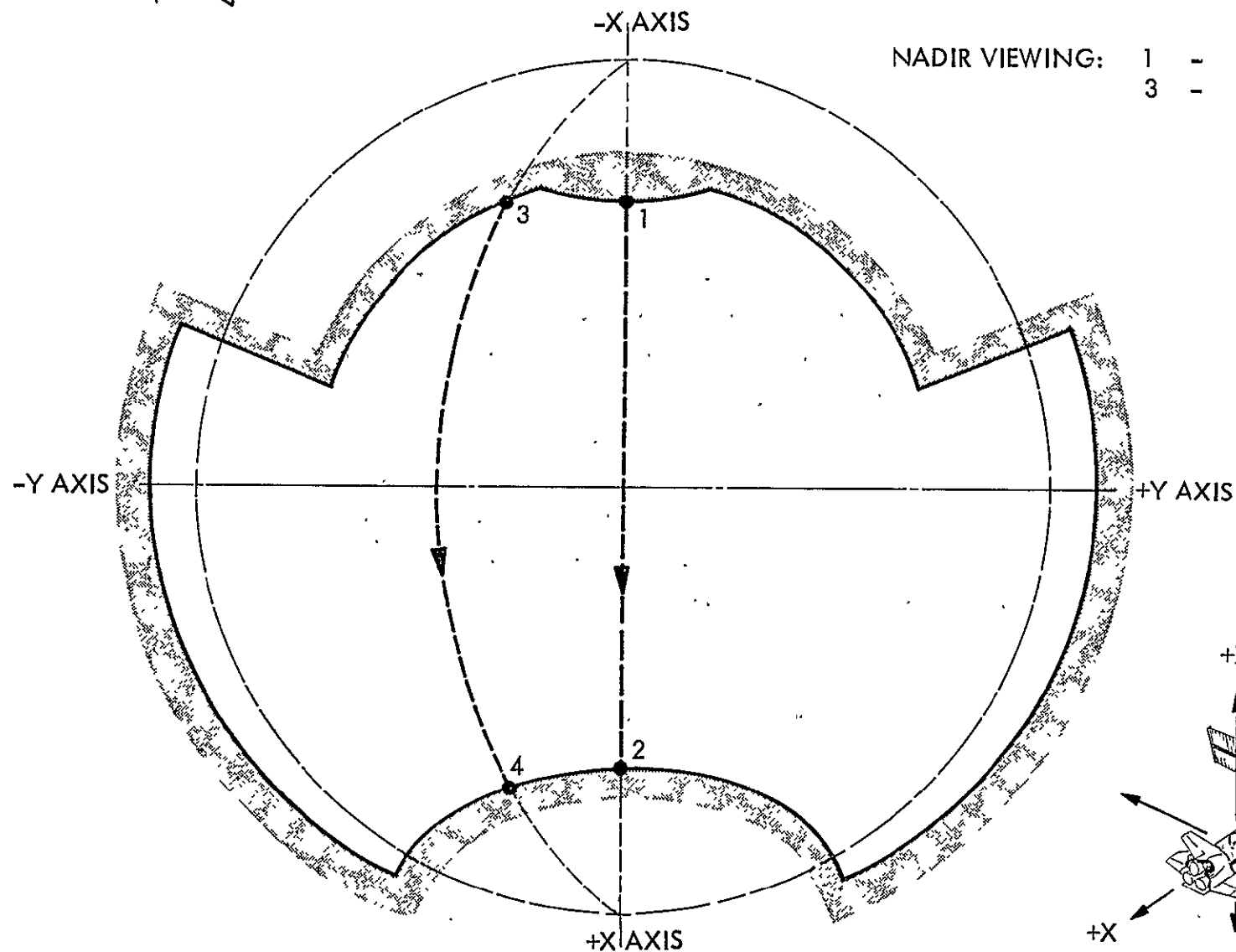
### NADIR VIEWING OPPORTUNITIES

- When the vehicle viewing mask is superimposed on the target track, the range of orbital angle over which the targets may be viewed may be seen. Thus, in the example chosen, the Nadir may be viewed between points 1 and 2 at zero beta and between points 3 and 4 at  $\beta = 40$  degrees.



# NADIR VIEWING OPPORTUNITIES

XIOP, ZSL ATTITUDE, FREE FLYER FORWARD PALLET



## STO MISSION VIEWING CAPABILITIES

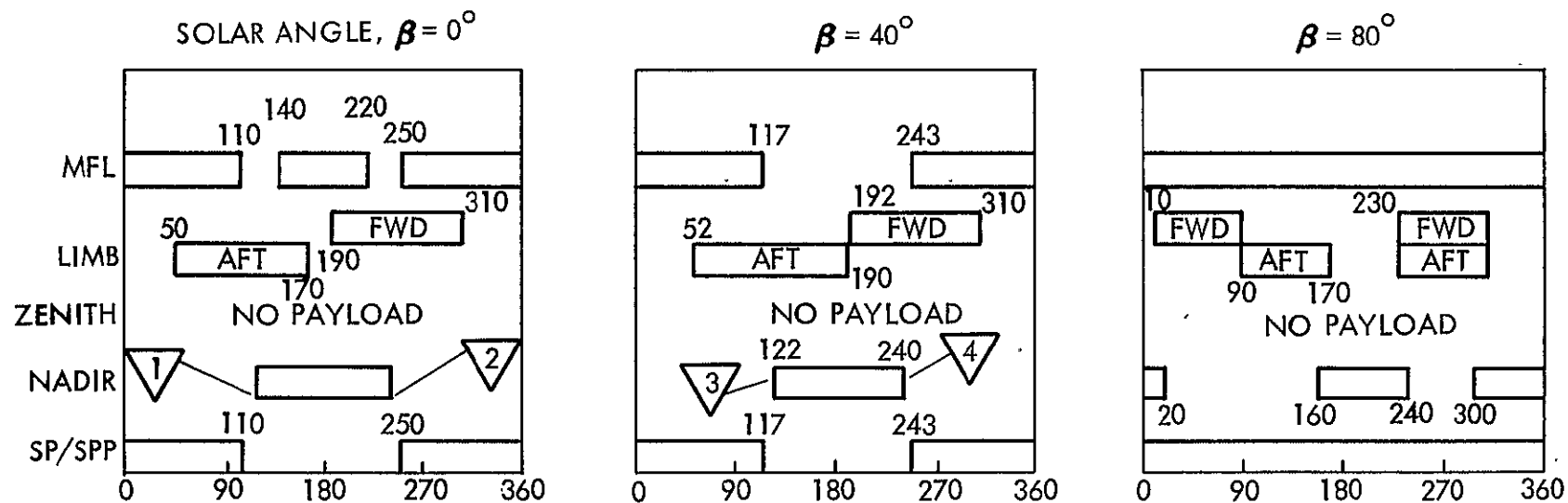
- The viewing capabilities for each of the targets of interest (Sun, Nadir, earth limb, zenith, magnetic field lines) were derived and are represented in the form of viewing capabilities bar charts as shown. From these bars, the amount of time available for viewing individual targets and for simultaneous viewing of targets may be seen readily. We can see that, in the example shown, simultaneous viewing of the earth limb and the sun is possible at low beta, but that the Sun and Nadir can not be viewed together.



# STO MISSION VIEWING CAPABILITIES

XIOP, ZSL, (PITCH = 0°) ATTITUDE – SORTIE

INCREMENT NO. 1



MFL – MAGNETIC FIELD LINES

SP/SPP – SOLAR PHYSICS/SOLAR POINTING PACKAGE

## STO VIEWING OPPORTUNITIES -- SORTIE MODE

- These data combine to give the available viewing time for each of the attitude modes for each target and combination of targets. Minus (M)XPOP represents  $B > 0^0$ .
- The chart shows the results for the sortie mode, STO increments 1 and 2. The data are presented for the five individual targets and for six target combinations considered to be of interest.
- These results are used, in conjunction with vehicle performance data, to develop an overall assessment of viewing capability.



# STO VIEWING OPPORTUNITIES—SORTIE MODE (MINUTES/REVOLUTION)

(M) = MINUS

MFL = MAGNETIC FIELD LINES

| INCR<br>NO. | TARGET       | (M)XPOP, Y PSL        |                    |     | ZPOP, Y PSL |                    |     | XIOP, ZSL |                    |     | XVV, ZLV |                    |     | (M)XPOP, ZLV |                    |     |
|-------------|--------------|-----------------------|--------------------|-----|-------------|--------------------|-----|-----------|--------------------|-----|----------|--------------------|-----|--------------|--------------------|-----|
|             |              | 0°                    | $\beta = 40^\circ$ | 80° | 0°          | $\beta = 40^\circ$ | 80° | 0°        | $\beta = 40^\circ$ | 80° | 0°       | $\beta = 40^\circ$ | 80° | 0°           | $\beta = 40^\circ$ | 80° |
| 1           | SUN          | 55                    | 58                 | 90  | 55          | 58                 | 90  | 55        | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | NADIR        | 50                    | 50                 | 50  | 40          | 40                 | 40  | 30        | 29                 | 40  | 90       | 90                 | 90  | 90           | 90                 | 90  |
|             | ZENITH       | ← NO PAYLOAD →        |                    |     |             |                    |     |           |                    |     |          |                    |     |              |                    |     |
|             | LIMB         | 85                    | 85                 | 85  | 60          | 60                 | 60  | 60        | 59                 | 60  | 0        | 0                  | 0   | 90           | 90                 | 90  |
|             | MFL          | 75                    | 58                 | 90  | 75          | 58                 | 90  | 75        | 58                 | 90  | 75       | 58                 | 90  | 75           | 58                 | 90  |
|             | SUN-NADIR    | 15                    | 18                 | 50  | 40          | 40                 | 40  | 0         | 0                  | 40  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | SUN-ZENITH   | ← NO ZENITH PAYLOAD → |                    |     |             |                    |     |           |                    |     |          |                    |     |              |                    |     |
|             | SUN-LIMB     | 50                    | 53                 | 85  | 25          | 28                 | 60  | 30        | 33                 | 60  | 0        | 0                  | 0   | 30           | 58                 | 90  |
|             | SUN-MFL      | 55                    | 58                 | 90  | 55          | 58                 | 90  | 55        | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | MFL-LIMB     | 70                    | 53                 | 85  | 45          | 28                 | 60  | 45        | 33                 | 60  | 0        | 0                  | 0   | 75           | 58                 | 90  |
| 2           | SUN-MFL-LIMB | 50                    | 53                 | 85  | 25          | 28                 | 60  | 30        | 33                 | 60  | 0        | 0                  | 0   | 30           | 58                 | 90  |
|             | SUN          | 55                    | 58                 | 90  | 55          | 58                 | 90  | 55        | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | NADIR        | 50                    | 50                 | 50  | 44          | 44                 | 44  | 31        | 30                 | 43  | 90       | 90                 | 90  | 90           | 90                 | 90  |
|             | ZENITH       | 50                    | 50                 | 50  | 42          | 42                 | 42  | 31        | 29                 | 43  | 0        | 0                  | 0   | 0            | 0                  | 0   |
|             | LIMB         | 85                    | 85                 | 85  | 60          | 60                 | 60  | 60        | 57                 | 40  | 0        | 0                  | 0   | 90           | 90                 | 90  |
|             | MFL          | 75                    | 58                 | 90  | 75          | 58                 | 90  | 75        | 58                 | 90  | 75       | 58                 | 90  | 75           | 58                 | 90  |
|             | SUN-NADIR    | 15                    | 18                 | 50  | 44          | 44                 | 44  | 0         | 0                  | 43  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | SUN-ZENITH   | 50                    | 50                 | 50  | 22          | 25                 | 42  | 31        | 29                 | 43  | 0        | 0                  | 0   | 0            | 0                  | 0   |
|             | SUN-LIMB     | 50                    | 53                 | 85  | 25          | 28                 | 60  | 30        | 32                 | 40  | 0        | 0                  | 0   | 30           | 58                 | 90  |
|             | SUN-MFL      | 55                    | 58                 | 90  | 55          | 58                 | 90  | 55        | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | MFL-LIMB     | 70                    | 53                 | 85  | 45          | 28                 | 60  | 45        | 32                 | 40  | 0        | 0                  | 0   | 75           | 58                 | 90  |
|             | SUN-MFL-LIMB | 50                    | 53                 | 85  | 25          | 28                 | 60  | 30        | 32                 | 40  | 0        | 0                  | 0   | 45           | 58                 | 90  |

# PM CAPABILITIES FOR STO (INERTIAL SORTIE MODES)

- This chart summarizes sortie vehicle capabilities in the three inertial attitude modes considered. All yield full 25 kW power generation and adequate heat rejection. However, only the XPOP mode provides long term attitude holding with 3 CMGs.
- Cyclical torques in the ZPOP mode will saturate the ACS in a small fraction of an orbit, but addition of one CMG will permit long term holding. The XIOP, ZSL mode will, likewise saturate very rapidly due to a combination of cyclical and bias torques. Addition of one CMG is required to handle cyclical torques plus a second CMG to handle the bias torques buildup in one orbit. Desaturation once per orbit will be required.



## PM CAPABILITIES FOR STO

(INERTIAL SORTIE MODES – MINIMUM VEHICLE)

|                          | <u>(XPOP, YPSL)</u>                                                                     | <u>(ZPOP, YPSL)</u>                                                                               | <u>(XIOP, ZSL)</u>                                                                    |
|--------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| POWER TO ORBITER/PAYLOAD | 25 kW – ALL BETAS                                                                       | 25 kW – ALL BETAS                                                                                 | 25 kW – ALL BETAS                                                                     |
| TOTAL HEAT REJECTION     | 54 kW – HIGH BETA<br>42.5 kW – LOW BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE     | 54 kW – LOW BETA<br>34.5 kW – HIGH BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE               | 42.5 kW – LOW BETA<br>34.5 kW – HIGH BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE |
| ATTITUDE HOLDING         | NO BIAS TORQUES<br>LOW CYCLICAL<br>TORQUES, DOES<br>NOT LIMIT<br>MISSION<br>PERFORMANCE | NO BIAS TORQUES<br>CYCLICAL TORQUES<br>LIMIT ATTITUDE<br>HOLDING TO 8.5<br>MINUTES (3 CMG<br>ACS) | CYCLICAL AND<br>BIAS TORQUES LIMIT<br>ATTITUDE HOLDING<br>TO <8.5 MIN (3 CMG<br>ACS)  |



PM CAPABILITIES FOR STO  
(EARTH ORIENTED SORTIE MODES)

- Vehicle performance is shown for the earth oriented modes considered. It is seen that, in these modes, neither heat rejection nor attitude holding will constrain the vehicle but power generation will vary with solar beta.



## PM CAPABILITIES FOR STO

(EARTH ORIENTED SORTIE MODES – MINIMUM VEHICLE)

|                          | <u>XVV, ZLV</u>                                                                      | <u>XPOP, ZLV</u>                                                                     |
|--------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| POWER TO ORBITER/PAYLOAD | 25 kW – 6 kW<br>FROM $\beta = 0$ TO $\beta = 80$                                     | 12 kW – 25 kW<br>FROM $\beta = 0$ TO $\beta = 80$                                    |
| TOTAL HEAT REJECTION     | 41.5 kW – LOW BETA<br>30.9 kW – HIGH BETA<br>DOES NOT LIMIT MIS-<br>SION PERFORMANCE | 41.5 kW – LOW BETA<br>39.1 kW – HIGH BETA<br>DOES NOT LIMIT MIS-<br>SION PERFORMANCE |
| ATTITUDE HOLDING         | NO GRAVITY GRADI-<br>ENT DISTURBING<br>TORQUES                                       | NO GRAVITY<br>GRADIENT DISTURBING<br>TORQUES                                         |

### STO VIEWING ASSESSMENT — SORTIE MODE

- When vehicle and attitude mode viewing capabilities are combined, it becomes possible to make a meaningful overall assessment of mission capability.
- The chart reflects the fact that the minimum vehicle can fly in the XPOP or earth oriented modes but that the earth oriented modes produce full power only at high or low values of beta. Thus, for full power at low beta, with the minimum vehicle available attitude modes will be XPOP, YPSL and XVV, ZLV. Addition of a fourth CMG would add the ZPOP, YPSL mode to those available. The experiment planner would select that available mode which maximizes ability to view the targets of interest and the chart is constructed on that basis.
- The results show that, in the sortie mode, the minimum vehicle provides at least 50 minutes/revolution viewing time for all phenomena except simultaneous viewing of Sun and Nadir.



# STO VIEWING ASSESSMENT-SORTIE MODE

(ATTITUDE MODES SELECTED FOR MAXIMUM VIEWING)

| TARGET<br>$\beta$ | MINIMUM VEHICLE<br>FULL POWER<br>0° 40° 80° |    |    | MINIMUM VEHICLE<br>REDUCED POWER<br>0° 40° 80° |    |    | 4 CMG ACS<br>FULL POWER<br>0° 40° 80° |    |    | 5 CMG ACS & DESAT<br>FULL POWER<br>0° 40° 80° |    |    |
|-------------------|---------------------------------------------|----|----|------------------------------------------------|----|----|---------------------------------------|----|----|-----------------------------------------------|----|----|
|                   | (MINUTES/REVOLUTION – INCREMENT 1)          |    |    |                                                |    |    |                                       |    |    |                                               |    |    |
| SUN               | 55                                          | 58 | 90 | 55                                             | 58 | 90 | 55                                    | 58 | 90 | 55                                            | 58 | 90 |
| NADIR             | 90                                          | 50 | 90 | 90                                             | 90 | 90 | 90                                    | 50 | 90 | 90                                            | 50 | 90 |
| ZENITH            | NO ZENITH PAYLOAD                           |    |    |                                                |    |    |                                       |    |    |                                               |    |    |
| LIMB              | 85                                          | 85 | 90 | 90                                             | 90 | 90 | 85                                    | 85 | 90 | 85                                            | 85 | 90 |
| MFL               | 75                                          | 58 | 90 | 75                                             | 58 | 90 | 75                                    | 58 | 90 | 75                                            | 58 | 90 |
| SUN-NADIR         | 30                                          | 18 | 90 | 30                                             | 58 | 90 | 40                                    | 40 | 90 | 40                                            | 40 | 90 |
| SUN-ZENITH        | NO ZENITH PAYLOAD                           |    |    |                                                |    |    |                                       |    |    |                                               |    |    |
| SUN-LIMB          | 50                                          | 53 | 90 | 50                                             | 58 | 90 | 50                                    | 53 | 90 | 50                                            | 53 | 90 |
| SUN-MFL           | 55                                          | 58 | 90 | 55                                             | 58 | 90 | 55                                    | 58 | 90 | 55                                            | 58 | 90 |
| MFL-LIMB          | 70                                          | 53 | 90 | 75                                             | 58 | 90 | 70                                    | 53 | 90 | 70                                            | 53 | 90 |
| SUN-MFL-LIMB      | 50                                          | 53 | 90 | 50                                             | 58 | 90 | 50                                    | 53 | 90 | 50                                            | 53 | 90 |

(MINUTES/REVOLUTION - INCREMENT 2)

|              |    |    |    |    |    |    |    |    |    |    |    |    |
|--------------|----|----|----|----|----|----|----|----|----|----|----|----|
| SUN          | 55 | 58 | 90 | 55 | 58 | 90 | 55 | 58 | 90 | 55 | 58 | 90 |
| NADIR        | 90 | 50 | 90 | 90 | 90 | 90 | 90 | 50 | 90 | 90 | 50 | 90 |
| ZENITH       | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| LIMB         | 85 | 85 | 90 | 90 | 90 | 90 | 85 | 85 | 90 | 85 | 85 | 90 |
| MFL          | 75 | 58 | 90 | 75 | 58 | 90 | 75 | 58 | 90 | 75 | 58 | 90 |
| SUN-NADIR    | 30 | 18 | 90 | 30 | 58 | 90 | 41 | 44 | 90 | 41 | 29 | 90 |
| SUN-ZENITH   | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| SUN-LIMB     | 50 | 53 | 90 | 50 | 58 | 90 | 50 | 53 | 90 | 50 | 53 | 90 |
| SUN-MFL      | 55 | 58 | 90 | 55 | 58 | 90 | 55 | 58 | 90 | 55 | 58 | 90 |
| MFL-LIMB     | 70 | 53 | 90 | 75 | 58 | 90 | 70 | 53 | 90 | 70 | 53 | 90 |
| SUN-MFL-LIMB | 50 | 53 | 90 | 50 | 58 | 90 | 50 | 53 | 90 | 50 | 53 | 90 |

## SUN-NADIR VIEWING OPPORTUNITIES

- The data presented does not provide a basis for assessing the adequacy of the Sun-Nadir viewing time achievable. Such an assessment would require examination of the scientific measurement program.
- The data shown here, however, addresses the more limited question of options available if the view time were judged not to be adequate.
- It can be seen that at low beta, the only option available for increasing view time is to fly in the ZPOP mode, which would require a fourth CMG. At mid beta, the fourth CMG option is available as well as flying in one of the earth oriented modes. These would, however reduce available power to 21 kW. If that reduction in power were not acceptable, the solar array could be made larger or given a second degree of freedom.



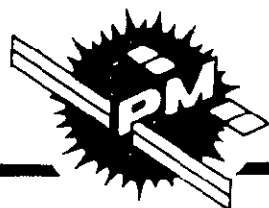
# SUN - NADIR VIEWING OPPORTUNITIES

## SORTIE MODE

|               |               | $\beta = 0$ |                     | $\beta = 40$ |                     | $\beta = 80$ |                     |
|---------------|---------------|-------------|---------------------|--------------|---------------------|--------------|---------------------|
| ATTITUDE MODE | A/C SYSTEM    | POWER (kW)  | VIEW TIME (MIN/REV) | POWER (kW)   | VIEW TIME (MIN/REV) | POWER (kW)   | VIEW TIME (MIN/REV) |
| XPOP, YPSL    | 3 CMG         | 25          | 15                  | 25           | 18                  | 25           | 50                  |
| XVV, ZLV      | 3 CMG         | 25          | 30                  | 20           | 41                  | 6            | 90                  |
| XPOP, ZLV     | 3 CMG         | 12          | 30                  | 21           | 58                  | 25           | 90                  |
| ZPOP, YPSL    | 4 CMG         | 25          | 40                  | 25           | 40                  | 25           | 40                  |
| XIOP, ZSL     | 5 CMG + DESAT | 25          | 0                   | 25           | 0                   | 25           | 40                  |

#### STO VIEWING OPPORTUNITIES – FREE-FLYER

- The process described for the sortie mission was repeated for the free flyer. The only differences were the elimination of the sortie pallet instruments and some reduction in vehicle blockage.
- Results of the application of this process are as shown.



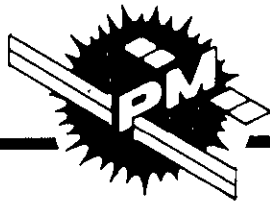
# STO VIEWING OPPORTUNITIES - FREE-FLYER (MINUTES/REVOLUTION)

| INCR<br>NO. | TARGET       | (M)XPOP, Y PSL |                    |     | ZPOP, Y PSL |                    |     | XIOP, ZSL         |                    |     | XVV, ZLV |                    |     | (M)XPOP, ZLV |                    |     |
|-------------|--------------|----------------|--------------------|-----|-------------|--------------------|-----|-------------------|--------------------|-----|----------|--------------------|-----|--------------|--------------------|-----|
|             |              | 0°             | $\beta = 40^\circ$ | 80° | 0°          | $\beta = 40^\circ$ | 80° | 0°                | $\beta = 40^\circ$ | 80° | 0°       | $\beta = 40^\circ$ | 80° | 0°           | $\beta = 40^\circ$ | 80° |
| 1           | SUN          | 55             | 58                 | 90  | 55          | 58                 | 90  | 55                | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | NADIR        | 50             | 50                 | 50  | 40          | 40                 | 40  | 30                | 29                 | 40  | 90       | 90                 | 90  | 90           | 90                 | 90  |
|             | ZENITH       | ←              |                    |     |             |                    |     | NO PAYLOAD        |                    |     |          |                    |     | →            |                    |     |
|             | LIMB         | 85             | 85                 | 85  | 60          | 60                 | 60  | 60                | 59                 | 60  | 0        | 0                  | 0   | 90           | 90                 | 90  |
|             | MFL          | 75             | 58                 | 90  | 75          | 58                 | 90  | 75                | 58                 | 90  | 75       | 58                 | 90  | 75           | 58                 | 90  |
|             | SUN-NADIR    | 15             | 18                 | 50  | 40          | 40                 | 40  | 0                 | 0                  | 40  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | SUN-ZENITH   | ←              |                    |     |             |                    |     | NO ZENITH PAYLOAD |                    |     |          |                    |     | →            |                    |     |
|             | SUN-LIMB     | 50             | 53                 | 85  | 25          | 28                 | 60  | 30                | 33                 | 60  | 0        | 0                  | 0   | 30           | 58                 | 90  |
|             | SUN-MFL      | 55             | 58                 | 90  | 55          | 58                 | 90  | 55                | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | MFL-LIMB     | 70             | 53                 | 85  | 45          | 28                 | 60  | 45                | 33                 | 60  | 0        | 0                  | 0   | 75           | 58                 | 90  |
| 2           | SUN-MFL-LIMB | 50             | 53                 | 85  | 25          | 28                 | 60  | 30                | 33                 | 60  | 0        | 0                  | 0   | 45           | 58                 | 90  |
|             | SUN          | 55             | 58                 | 90  | 55          | 58                 | 90  | 55                | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | NADIR        | 50             | 50                 | 50  | 44          | 44                 | 44  | 31                | 30                 | 43  | 90       | 90                 | 90  | 90           | 90                 | 90  |
|             | ZENITH       | 50             | 50                 | 50  | 42          | 42                 | 42  | 31                | 29                 | 43  | 0        | 0                  | 0   | 0            | 0                  | 0   |
|             | LIMB         | 85             | 85                 | 85  | 65          | 65                 | 65  | 60                | 57                 | 45  | 0        | 0                  | 0   | 90           | 90                 | 90  |
|             | MFL          | 75             | 58                 | 90  | 75          | 58                 | 90  | 75                | 58                 | 90  | 75       | 58                 | 90  | 75           | 58                 | 90  |
|             | SUN-NADIR    | 15             | 18                 | 50  | 44          | 44                 | 44  | 0                 | 0                  | 43  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | SUN-ZENITH   | 50             | 50                 | 50  | 22          | 25                 | 42  | 31                | 29                 | 43  | 0        | 0                  | 0   | 0            | 0                  | 0   |
|             | SUN-LIMB     | 50             | 53                 | 85  | 30          | 34                 | 65  | 30                | 32                 | 45  | 0        | 0                  | 0   | 30           | 58                 | 90  |
|             | SUN-MFL      | 55             | 58                 | 90  | 55          | 58                 | 90  | 55                | 58                 | 90  | 30       | 41                 | 90  | 30           | 58                 | 90  |
|             | MFL-LIMB     | 70             | 53                 | 85  | 50          | 54                 | 65  | 45                | 32                 | 45  | 0        | 0                  | 0   | 75           | 58                 | 90  |
|             | SUN-MFL-LIMB | 50             | 53                 | 85  | 30          | 34                 | 65  | 30                | 32                 | 45  | 0        | 0                  | 0   | 45           | 58                 | 90  |



PM CAPABILITIES FOR STO  
(INERTIAL FREE FLYER MODES)

- This chart, and the next following, summarize the performance of the free-flyer vehicle. Differences from the sortie mode are:
  - Attitude holding restrictions are relaxed. The ZPOP, YPSL mode is within the capability of the minimum vehicle and the XIOP, ZSL mode can be held by the minimum vehicle for at least 2.5 hours.
  - Heat rejection capability is reduced due to the absence of the orbiter radiators. A power profile and heat flow analysis is required to ascertain whether payload pallet radiators are needed.
  - As discussed earlier, an attitude sensor is required to permit achieving and holding the specified attitudes.



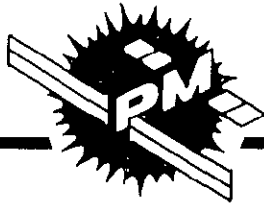
## PM CAPABILITIES FOR STO

(INERTIAL FREE FLYER MODES – MINIMUM VEHICLE)

|                      | <u>(XPOP, YPSI)</u>                                                                          | <u>(ZPOP, YPSL)</u>                                                                 | <u>(XIOP, ZSL)</u>                                                                |
|----------------------|----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| POWER TO PAYLOAD     | 25 kW – ALL BETAS                                                                            | 25 kW – ALL BETAS                                                                   | 25 kW – ALL BETAS                                                                 |
| TOTAL HEAT REJECTION | 22.4 kW – HIGH BETA<br>18.7 kW – LOW BETA                                                    | 22.4 kW – LOW BETA<br>16.3 kW – HIGH BETA                                           | 18.7 kW – LOW BETA<br>16.3 kW – HIGH BETA                                         |
|                      | MAY REQUIRE PAY-<br>LOAD RADIATOR FOR<br>INCREMENT 2                                         | MAY REQUIRE PAY-<br>LOAD RADIATOR FOR<br>INCREMENTS 1 & 2                           | MAY REQUIRE PAY-<br>LOAD RADIATOR FOR<br>INCREMENTS 1 & 2                         |
| ATTITUDE HOLDING     | NO BIAS TORQUES,<br>LOW CYCLICAL<br>TORQUES, DOES<br>NOT LIMIT MIS-<br>SION PERFORM-<br>ANCE | NO BIAS TORQUES,<br>CYCLICAL TORQUES<br>WITHIN CAPABILITY<br>OF MINIMUM SYS-<br>TEM | CYCLICAL AND BIAS<br>TORQUES WILL<br>REQUIRE DESATURA-<br>TION AFTER 2.5<br>HOURS |

PM CAPABILITIES FOR STO  
(EARTH ORIENTED FREE-FLYER MODES)

- Refer to the discussion with the preceding chart.



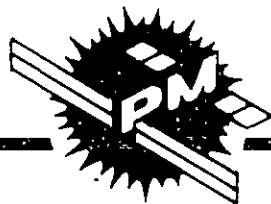
## PM CAPABILITIES FOR STO

(EARTH ORIENTED FREE-FLYER MODES – MINIMUM VEHICLE)

|                          | <u>XVV, ZLV</u>                                                                                         | <u>XPOP, ZLV</u>                                                                                  |
|--------------------------|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| POWER TO ORBITER/PAYLOAD | 25 kW – 6 kW<br>FROM $\beta=0$ TO $\beta=80$                                                            | 12 kW – 25 kW<br>FROM $\beta=0$ TO $\beta=80$                                                     |
| TOTAL HEAT REJECTION     | 20.6 kW – LOW BETA<br>15.9 kW – HIGH BETA<br>MAY REQUIRE PAYLOAD<br>RADIATOR FOR INCRE-<br>MENT 1 AND 2 | 20.6 kW – LOW BETA<br>19.5 kW – HIGH BETA<br>MAY REQUIRE PAY-<br>LOAD RADIATOR FOR<br>INCREMENT 2 |
| ATTITUDE HOLDING         | NO GRAVITY GRADI-<br>ENT DISTURBING<br>TORQUES                                                          | NO GRAVITY GRADI-<br>ENT DISTURBING<br>TORQUES                                                    |

### STO VIEWING ASSESSMENT – FREE-FLYER MODE

- Using the same process, as for sortie missions, of selecting the best available attitude mode, an assessment of free-flyer capability was developed.
- It is seen that the minimum vehicle provides at least 50 minutes of viewing time for all targets except Sun-Nadir viewing. In this latter case, view time is 40 minutes or greater.
- There appears to be no benefit derived from augmenting the ACS system for this mission.



# STO VIEWING ASSESSMENT - FREE FLYER MODE

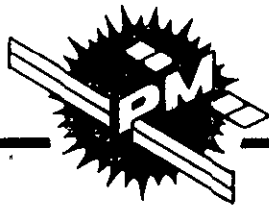
LMSC-D614944-5

## ATTITUDE MODES SELECTED FOR MAXIMUM VIEWING

| TARGET<br>$\beta$ | MINIMUM ACS<br>FULL POWER<br>0° 40° 80° |    |    | MINIMUM ACS<br>REDUCED POWER<br>0° 40° 80° |    |    | MINIMUM ACS & DESAT<br>FULL POWER<br>0° 40° 80° |    |    |
|-------------------|-----------------------------------------|----|----|--------------------------------------------|----|----|-------------------------------------------------|----|----|
|                   | (MINUTES/REVOLUTION – INCREMENT 1)      |    |    |                                            |    |    |                                                 |    |    |
| SUN               | 55                                      | 58 | 90 | 55                                         | 58 | 90 | 55                                              | 58 | 90 |
| NADIR             | 90                                      | 50 | 90 | 90                                         | 90 | 90 | 90                                              | 50 | 90 |
| ZENITH            |                                         |    |    | NO ZENITH PAYLOAD                          |    |    |                                                 |    |    |
| LIMB              | 85                                      | 85 | 90 | 90                                         | 90 | 90 | 85                                              | 85 | 90 |
| MFL               | 75                                      | 58 | 90 | 75                                         | 58 | 90 | 75                                              | 58 | 90 |
| SUN-NADIR         | 40                                      | 40 | 90 | 40                                         | 58 | 90 | 40                                              | 40 | 90 |
| SUN-ZENITH        |                                         |    |    | NO ZENITH PAYLOAD                          |    |    |                                                 |    |    |
| SUN-LIMB          | 50                                      | 53 | 90 | 50                                         | 58 | 90 | 50                                              | 53 | 90 |
| SUN-MFL           | 55                                      | 58 | 90 | 55                                         | 58 | 90 | 55                                              | 58 | 90 |
| MFL-LIMB          | 70                                      | 53 | 90 | 75                                         | 58 | 90 | 70                                              | 53 | 90 |
| SUN-MFL-LIMB      | 50                                      | 53 | 90 | 50                                         | 58 | 90 | 50                                              | 53 | 90 |
|                   | (MINUTES/REVOLUTION – INCREMENT 2)      |    |    |                                            |    |    |                                                 |    |    |
| SUN               | 55                                      | 58 | 90 | 55                                         | 58 | 90 | 55                                              | 58 | 90 |
| NADIR             | 90                                      | 50 | 90 | 90                                         | 90 | 90 | 90                                              | 50 | 90 |
| ZENITH            | 50                                      | 50 | 50 | 50                                         | 50 | 50 | 50                                              | 50 | 50 |
| LIMB              | 85                                      | 85 | 90 | 90                                         | 90 | 90 | 85                                              | 85 | 90 |
| MFL               | 75                                      | 58 | 90 | 75                                         | 58 | 90 | 75                                              | 58 | 90 |
| SUN-NADIR         | 44                                      | 44 | 90 | 44                                         | 58 | 90 | 44                                              | 44 | 90 |
| SUN-ZENITH        | 50                                      | 50 | 50 | 50                                         | 50 | 50 | 50                                              | 50 | 50 |
| SUN-LIMB          | 50                                      | 53 | 90 | 50                                         | 58 | 90 | 50                                              | 53 | 90 |
| SUN-MFL           | 55                                      | 58 | 90 | 55                                         | 58 | 90 | 55                                              | 58 | 90 |
| MFL-LIMB          | 70                                      | 53 | 90 | 75                                         | 58 | 90 | 70                                              | 53 | 90 |
| SUN-MFL-LIMB      | 50                                      | 53 | 90 | 50                                         | 58 | 90 | 50                                              | 53 | 90 |

## STO MISSION ACCOMMODATION

- The results of the STO assessment are summarized here:
  - Power generation is adequate for free flyer missions but requires further analysis for the sortie cases.
  - Heat rejection in the sortie mode is adequate to handle all power generated. Analysis is required to establish requirements for free flyer payload radiators.
  - The minimum ACS accommodates the STO sortie mission and with the addition of an attitude sensor, the free flyer STO mission.
  - The available vehicle minimum attitude modes provide substantial viewing capability with a possible deficiency in Sun-Nadir simultaneous sortie viewing. Analyses of the type shown in the sample experiment discussion are required for a more definitive assessment of viewing capability.



# STO MISSION ACCOMMODATION

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## SUMMARY OF FINDINGS

### POWER/HEAT REJECTION

- EXPERIMENT TIMELINE ANALYSIS REQUIRED TO CONFIRM ADEQUACY OF AVAILABLE POWER (SORTIE MODE) AND TO ESTABLISH REQUIREMENTS FOR PAYLOAD RADIATORS (FREE-FLYER).

### ATTITUDE CONTROL

- MINIMUM VEHICLE ACCOMMODATES SORTIE MISSION
- FREE-FLYER MISSION REQUIRES ATTITUDE SENSOR

### VIEWING CAPABILITY

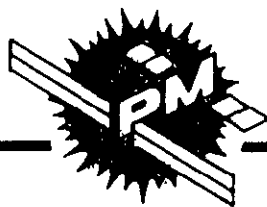
- MINIMUM VEHICLE PROVIDES AT LEAST 50 MINUTES/ORBIT VIEWING EXCEPT SUN-NADIR SIMULTANEOUS OBSERVATION
- OPTIONS FOR INCREASED SUN-NADIR SORTIE VIEW TIME
  - ADD 1 CMG TO ACS (40 MINUTES – ALL BETA)
  - ACCEPT REDUCED POWER (21 KW – 58 MINUTES AT BETA = 40°)
  - SOLAR ARRAY SECOND DEGREE OF FREEDOM
- EXPERIMENT TIMELINE ANALYSIS NEEDED TO ASSESS VIEWING ADEQUACY



### 3.3.2 Material Processing/Life Sciences (MP/LS)

#### MATERIAL PROCESSING – LIFE SCIENCES MISSION REQUIREMENTS

- The principal requirement of these missions is an acceleration-free environment for periods of hours to days. Longer durations, permitting exploration of additional phenomena are highly desirable.
- $10^{-5}$  g is used as a practical approximation of a zero gravity condition. These missions impose no attitude requirements other than stability.



# **MATERIAL PROCESSING - LIFE SCIENCES MISSION REQUIREMENTS**

---

MISSIONS COMBINED FOR ANALYSIS DUE TO COMMON MISSION  
REQUIREMENTS

|                         |                                                                                |
|-------------------------|--------------------------------------------------------------------------------|
| MISSION OBJECTIVE:      | INVESTIGATE PHYSICAL AND BIOLOGICAL<br>PROCESSES UNDER ZERO GRAVITY CONDITIONS |
| POWER REQUIREMENTS:     | HIGH POWER (PERMITS CONDUCT OF EXPERIMENTS<br>IN PARALLEL)                     |
| STABILITY REQUIREMENTS: | FORCES AT EXPERIMENT NOT TO EXCEED $10^{-5}G$                                  |
| OBSERVATION DURATION:   | REQUIRES HOURS TO DAYS (LONGER TIMES HIGHLY<br>DESIRABLE)                      |
| ORBIT:                  | ANY USABLE, $28.5^{\circ}$ INCLINATION PREFERRED                               |

## CAPABILITIES FOR MPS/LIFE SCIENCE SORTIE MISSIONS

- The basic requirement for this mission is long term freedom from disturbing forces, combined with maximum power. Two kinds of attitude modes provide these conditions:
  1. An inertial mode with the principal (X) axis perpendicular to the orbit plane and the Y axis perpendicular to the sun line.
  2. An earth oriented mode with the principal axis vertical with either ZVV where  $\beta$  is low, or ZPOP when  $\beta$  is high.
- For the orientations shown, the only constraint is the limitation of the power available to orbiter/payload as a function of beta angle in XLV. But, since the performance of the XLV modes are complementary in this respect, the limitation is largely removed by properly selecting ZVV or ZPOP when flying XLV. However, for these modes there is a reduction of available power to 21 kW at mid values of beta. This situation could be corrected by adding an additional degree of freedom to the solar array.



## CAPABILITIES FOR MPS/LIFE SCIENCE SORTIE MISSIONS

|                                 | <u>XPOP, YPSL</u>                                                                        | <u>XLV, ZVV</u>                                              | <u>XLV, ZPOP</u>                                                                      |
|---------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <u>POWER TO ORBITER/PAYLOAD</u> | 25 kW – ALL BETAS                                                                        | 25 kW – 0° BETA<br>20 kW – 40°<br>6 kW – 80°                 | 12 kW – 0° BETA<br>21 kW – 40°<br>25 kW – 80°                                         |
| <u>TOTAL HEAT REJECTION</u>     | 54 kW – HIGH BETA<br>42.5 kW – LOW BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE      | 51.6 kW ALL BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE | 50.5 kW – LOW BETA<br>47.8 kW – HIGH BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE |
| <u>ATTITUDE HOLDING *</u>       | NO BIAS TORQUES,<br>LOW CYCLICAL<br>TORQUES, DOES<br>NOT LIMIT<br>MISSION<br>PERFORMANCE | NO GRAVITY<br>GRADIENT DISTURB-<br>ING TORQUES               | NO GRAVITY<br>GRADIENT DISTURB-<br>ING TORQUES                                        |

\* ATTITUDE CONTROL BY CMG TORQUE. SHUTTLE RCS/VCS OPERATION NOT REQUIRED.

#### CAPABILITIES FOR MPS/LIFE SCIENCE FREE-FLYER MISSIONS

- In the absence of an attitude reference, the free-flyer missions can be accommodated with respect to power by proper selection of the Z orientation as a function of beta angle when in the XLV orientation. Available power will be limited to 21 kW at worst beta. However, the heat rejection requirements will require the addition of payload radiators for all orientations considered here.



## CAPABILITIES FOR MPS/LIFE SCIENCE FREE-FLYER MISSIONS

|                                 | <u>XPOP, YPSL</u>                                                                        | <u>XLV, ZVV</u>                                           | <u>XLV, ZPOP</u>                                                               |
|---------------------------------|------------------------------------------------------------------------------------------|-----------------------------------------------------------|--------------------------------------------------------------------------------|
| <u>POWER TO ORBITER/PAYLOAD</u> | 25 kW – ALL BETAS                                                                        | 25 kW – 0° BETA<br>20 kW – 40° BETA<br>6 kW – 80° BETA    | 12 kW – 0° BETA<br>21 kW – 40° BETA<br>25 kW – 80° BETA                        |
| <u>TOTAL HEAT REJECTION</u>     | 22.4 kW – HIGH BETA<br>22.4 kW – LOW BETA<br>WILL REQUIRE PAYLOAD<br>RADIATORS           | 20.6 kW ALL BETA<br><br>WILL REQUIRE<br>PAYLOAD RADIATORS | 16.6 kW – LOW BETA<br>20.6 kW – HIGH BETA<br>WILL REQUIRE<br>PAYLOAD RADIATORS |
| <u>ATTITUDE HOLDING</u>         | NO BIAS TORQUES,<br>LOW CYCLICAL<br>TORQUES,<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE | NO GRAVITY GRADIENT<br>DISTURBING TORQUES                 | NO GRAVITY GRADIENT<br>DISTURBING TORQUES                                      |
| <u>ATTITUDE REFERENCE</u>       | REQUIRED                                                                                 | NOT REQUIRED                                              | NOT REQUIRED                                                                   |

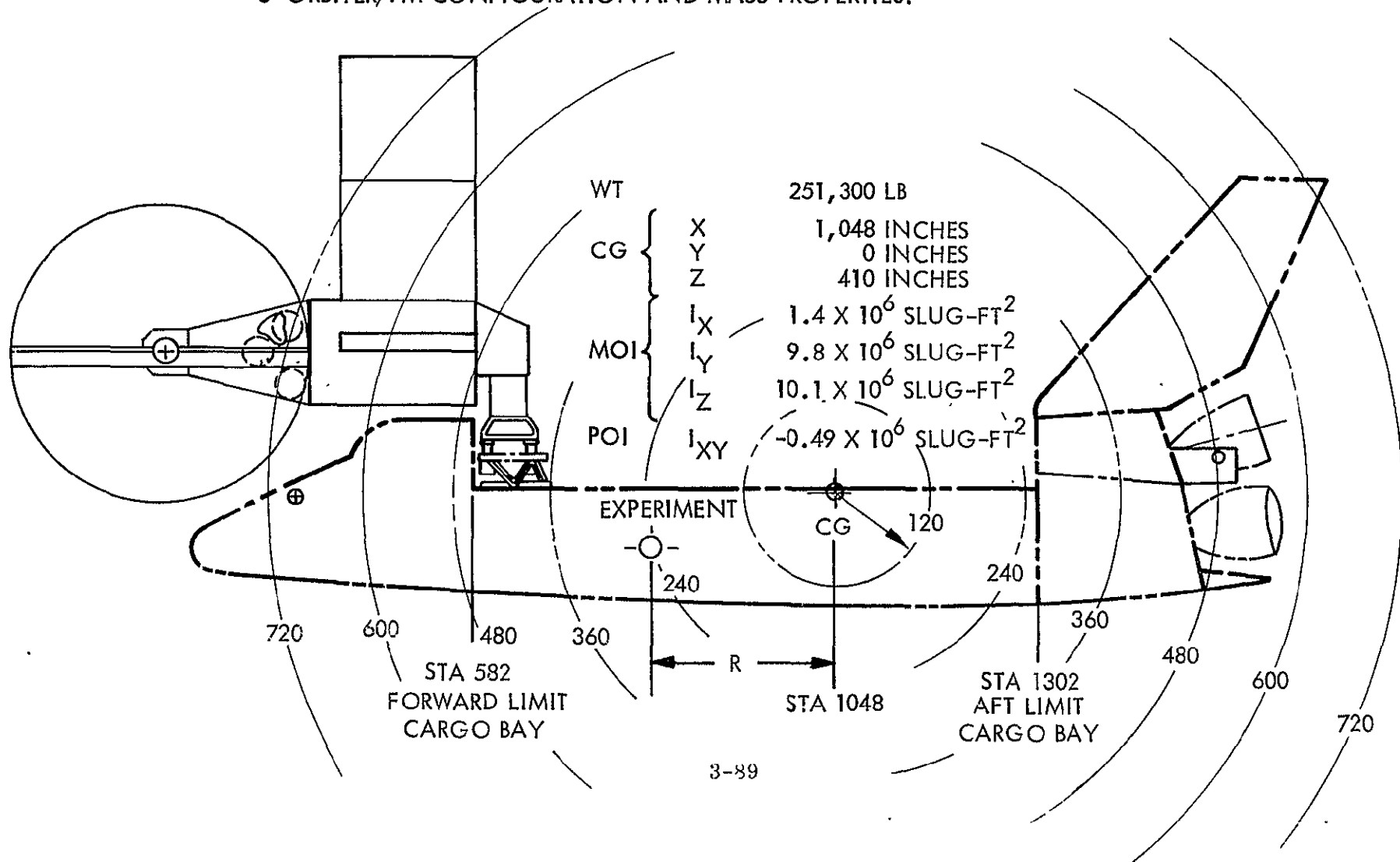
#### MPS/LIFE SCIENCES ROTATIONAL FORCES – ANALYSIS APPROACH

- The physical characteristics of the power module/orbiter configuration utilized in the acceleration level analysis is shown.
- It is seen that the center of gravity of the cluster is located in the cargo bay approximately 21 feet forward of the aft bulkhead. This is the area which would normally be occupied by the experiment packages.



# MPS/LIFE SCIENCES ROTATIONAL FORCES ANALYSIS APPROACH

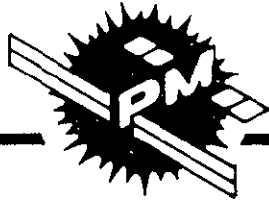
- DISTURBANCE TORQUES CAUSE ACCELERATION ABOUT CG
- G LEVEL AT EXPERIMENT PACKAGE IS A FUNCTION OF DISTANCE FROM CG (R)
- ORBITER/PM CONFIGURATION AND MASS PROPERTIES:





MPS/LIFE SCIENCES ROTATIONAL FORCES --  
ANALYSIS PROCESS

- For the power module/orbiter configuration shown on the previous page, the distance from the cluster center of mass for which  $10^{-5}$  g is satisfied was computed for a number of disturbances. A 0.01 Hz bandwidth attitude control system was assumed.



## MPS/LIFE SCIENCES ROTATIONAL FORCES ANALYSIS PROCESS

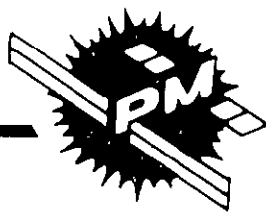
---

COMPUTE THE DISTANCE FROM THE CLUSTER CENTER OF MASS FOR WHICH  $10^{-5}G$  IS SATISFIED, CONSIDERING:

- POWER MODULE/ORBITER SORTIE CONFIGURATION
- X-LOCAL VERTICAL AND X-PERPENDICULAR TO ORBIT PLANE ATTITUDE
- ASSUMED 0.01 Hz CONTROL SYSTEM
- DISTURBANCES EXAMINED: CREW MOTION, SOLAR PANEL DRIVE, CMG SYSTEM UNBALANCE, GRAVITY GRADIENT FORCES, COOLANT LOOP EFFECTS

MPS/LIFE SCIENCES ROTATIONAL FORCES-  
DISTURBANCES CONSIDERED

- Representative disturbances to be encountered were formulated.
- The assumed crew motion disturbance produces an impulse of a 25-pound wall push-off.
- The CMG unbalance data was taken from previous analyses.



## **MPS/LIFE SCIENCES ROTATIONAL FORCES DISTURBANCES CONSIDERED**

---

- CREW MOTION DISTURBANCE  
9 POUND FORCE, 50 FEET FROM CENTER OF MASS (ORBITER CABIN),  
FOR ONE SECOND
- SOLAR PANEL DRIVE  
5 FOOT-POUND TORQUE FOR ONE SECOND
- CMG SYSTEM UNBALANCE  
22 MICRO-INCH WHEEL UNBALANCE  
3 ATM CMGs, 60 FEET FROM CENTER OF MASS  
FREQUENCY OF UNBALANCE FORCE IS 150 Hz
- GRAVITY GRADIENT DISTURBING TORQUES  
ORBITAL PERIOD OF 90 MINUTES
- COOLANT LOOP EFFECTS  
ACCELERATING 200 LB FLUID IN RADIATOR TO 4 FT/SEC IN 120 SECONDS.

#### MPS/LIFE SCIENCES ROTATIONAL FORCES – RESULTS

- The analysis results indicate that only crew motion disturbances are significant with respect to acceleration level. The CMG system unbalance effects can be filtered out structurally due to their relatively high frequency (150 Hz).



## MPS/LIFE SCIENCES ROTATIONAL FORCES RESULTS

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| DISTURBANCE          | MAXIMUM DISTANCE (FEET) —<br>CLUSTER CENTER OF MASS TO<br>EXPERIMENT FOR $10^{-5} G$ * |
|----------------------|----------------------------------------------------------------------------------------|
| CREW MOTION          | 27                                                                                     |
| SOLAR PANEL DRIVE    | 2432                                                                                   |
| CMG SYSTEM UNBALANCE | > 27 AFTER STRUCTURAL FILTER-<br>ING AND ISOLATION (150 Hz)                            |
| GRAVITY GRADIENT     |                                                                                        |
| X-LOCAL VERTICAL     | 79                                                                                     |
| X-POP                | 3000                                                                                   |
| COOLANT LOOP EFFECT  | 3522                                                                                   |

\* ROTATIONAL ACCELERATIONS PROPORTIONAL TO DISTANCE  
FROM CENTER OF MASS.

# MPS/LIFE SCIENCES – TRANSLATIONAL FORCES

- The linear translation resulting from a wall push-off by a crew member causes a  $10^{-4}$  g acceleration for 0.8 seconds. In the model used for this analysis it was assumed that 1.6 seconds elapsed before an equal and opposite push-off occurred. The total vehicle displacement using this model was 0.0273 inches, which is the magnitude of the sway space required if the entire experiment package were to be levitated.
- Aerodynamic drag was found to cause no violation of the  $10^{-5}$  g requirement.



## MPS/LIFE SCIENCES — TRANSLATIONAL FORCES

- WALL PUSHOFF CREW DISTURBANCE

0 TO 100 NEWTONS (22.48 LB) IN 0.8 SECONDS

ACCELERATION

$$a = \frac{F}{M} = \frac{22.48 \text{ LB}}{250,000 \text{ LB}} \quad g \approx 10^{-4} g \text{ FOR 0.8 SECONDS}$$

DISPLACEMENT

ASSUMING 1.6 SECONDS BETWEEN TWO COUNTERACTING PUSHOFFS  
 $S = 0.0273$  INCHES

- AERODYNAMIC DRAG (1959 ARDC MODEL)

SORTIE

17,000 FT<sup>2</sup> → 0.17 LB

ACCELERATION

$$a = \frac{F}{M} = \frac{0.17}{250,000} = 0.7 \cdot 10^{-6} g$$

FREE-FLYER

11,000 FT<sup>2</sup> → 0.10 LB

$$a = \frac{F}{M} = \frac{0.10}{29,000} = 3.4 \cdot 10^{-6} g$$



MPS/LIFE SCIENCES  
SUMMARY OF FINDINGS

- The analyses conducted indicate that MPS/Life Sciences missions can be accommodated by the Power Module in both the free-flyer and sortie modes.
- In the absence of an attitude sensor or a second degree of solar array freedom, a power reduction to 21 kW must be accepted when beta is in the mid range.



## MPS/LIFE SCIENCES SUMMARY OF FINDINGS

---

- $10^{-5}G$  LEVEL OBTAINABLE IN XPOP OR XLV ATTITUDES (ROTATIONAL DISTURBANCES AND AIR DRAG). AFT 50 FEET OF SHUTTLE CARGO BAY PROVIDES  $10^{-5}G$  CONDITIONS.
- CREW DISTURBANCE (SORTIE MODE) CAN PRODUCE TRANSLATIONAL ACCELERATIONS  $\sim 10^{-4}G$  FOR 0.8 SECONDS (ORBITER PROBLEM UNRELATED TO POWER MODULE – MAXIMUM DISPLACEMENT < 0.03 INCHES).
- XPOP ATTITUDE PROVIDES 25 kW POWER AT ALL VALUES OF BETA. FREE-FLYER VEHICLE REQUIRES ATTITUDE SENSOR TO FLY IN XPOP ATTITUDE.
- XLV ATTITUDE HAS REDUCED POWER (21 kW) AT MID VALUES OF  $\beta$ . CAN BE FLOWN BY A MINIMUM FREE-FLYER POWER MODULE.
- VIBRATION ISOLATION MAY BE REQUIRED TO FILTER CMG UNBALANCE NOISE AT 150 Hz.

### 3.3.3 Stellar Observation

#### STELLAR MISSION REQUIREMENTS OVERVIEW

- Stellar instruments tend to be relatively low in power but demanding in terms of pointing accuracy and stability and to involve relatively long observation times.
- These pointing requirements need not necessarily be satisfied entirely by the vehicle; the instrument package can include a fine pointing package. This could provide the ability to train the instrument over a wide area (eg, IPS) or it could provide only a vernier pointing capability. There is, thus, a potential area for trading vehicle and instrument package characteristics.



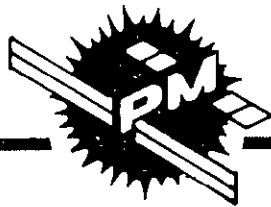
## STELLAR MISSION REQUIREMENTS OVERVIEW

---

|                        |                                                                       |
|------------------------|-----------------------------------------------------------------------|
| MISSION OBJECTIVES:    | MULTI-SPECTRAL EXAMINATION OF SELECTED CELESTIAL REGIONS.             |
| POWER REQUIREMENTS:    | LOW (2 – 3 KW)                                                        |
| ATTITUDE REQUIREMENTS: | P/L INSTRUMENTS TO COVER CELESTIAL SPHERE                             |
| POINTING ACCURACY:     | MINUTES OF ARC (PAYLOAD MAY INCLUDE FINE POINTING PACKAGE AND SENSOR) |
| POINTING STABILITY:    | MINUTES OF ARC                                                        |
| OBSERVATION DURATION:  | 20 MINUTES – 24 HOURS (INTERRUPTIONS ALLOWED)                         |

## STELLAR OBSERVATION MISSION ANALYSIS

- The chart summarizes the approach employed here to assess the capability of the power module to conduct stellar observation missions. Two orbits and three pointing modes (vehicle and instrument) were defined and four target areas of physical interest designated.
- The process was to define viewing opportunities over a year, taking into account instrument coverage (pointing mode determined), power generation, and solar exclusion.
- These data were then combined and related to vehicle characteristics to provide a total system capability assessment.



# STELLAR OBSERVATION MISSION ANALYSIS

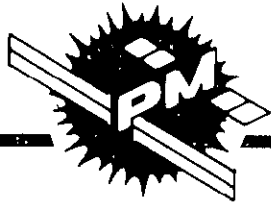
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- ORBITS CONSIDERED
  - $28.5^{\circ}$ , 235 NMI
  - $57^{\circ}$ , 235 NMI
  - NOON ASCENDING NODE – 21 JAN
- POINTING MODES CONSIDERED
  - XPOP, YPSL +  $\pm 60^{\circ}$  EXPERIMENT POINTING
  - ZPOP, YPSL +  $\pm 60^{\circ}$  EXPERIMENT POINTING
  - XIOP, ZSI
- TYPICAL TARGETS CONSIDERED
  - HYADES CLUSTER
  - GALACTIC CENTER
  - VIRGO CLUSTER
  - SMALL MAGELLANIC CLOUD
- IDENTIFY VIEWING OPPORTUNITIES FOR YEAR BASED UPON:
  - INSTRUMENT COVERAGE (XPOP, ZPOP ORIENTATIONS)
  - 20 AND 25 kW POWER OUTPUT (ZSI ORIENTATION)
  - SOLAR EXCLUSION
  - CONTINUOUS VIEWING (ZPOP, ZSI ORIENTATIONS)
- ASSESS MISSION OPPORTUNITIES VS POWER MODULE DESIGN PARAMETERS

### STELLAR OBSERVATION MISSION ALTERNATIVES

- This chart summarizes the characteristics of the three attitude modes included in the analysis.



## STELLAR OBSERVATION MISSION ALTERNATIVES

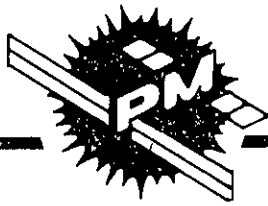
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- XPOP, YPSL ATTITUDE
  - VIEWING NEAR ORBIT PLANE
  - LONG TERM HOLD WITH 3 CMGs
  - 25 kW POWER
  - REQUIRES WIDE FIELD INSTRUMENT POINTING PACKAGE ( $\pm 60^\circ$ )
  
- ZPOP, YPSL ATTITUDE
  - VIEWING AT HIGH ORBIT LATITUDES
  - REQUIRES 4 CMGs FOR LONG-TERM HOLD (SORTIE MODE)
  - 25 kW POWER
  - REQUIRES WIDE FIELD INSTRUMENT POINTING PACKAGE ( $\pm 60^\circ$ )
  - LONG TERM VIEWING POSSIBLE
  
- XIOP, ZSI ATTITUDE
  - VIEWING AT ALL LATITUDES AND LONGITUDES
  - REQUIRES 5 CMGs AND DESATURATION EACH REVOLUTION (SORTIE MODE). FREE-FLYER WITH 3CMG ACS REQUIRES DESATURATION AFTER 150 MINUTES
  - POWER VARIES WITH BETA AND TARGET LOCATION
  - LONG TERM VIEWING LIMITED BY ATTITUDE CONTROL

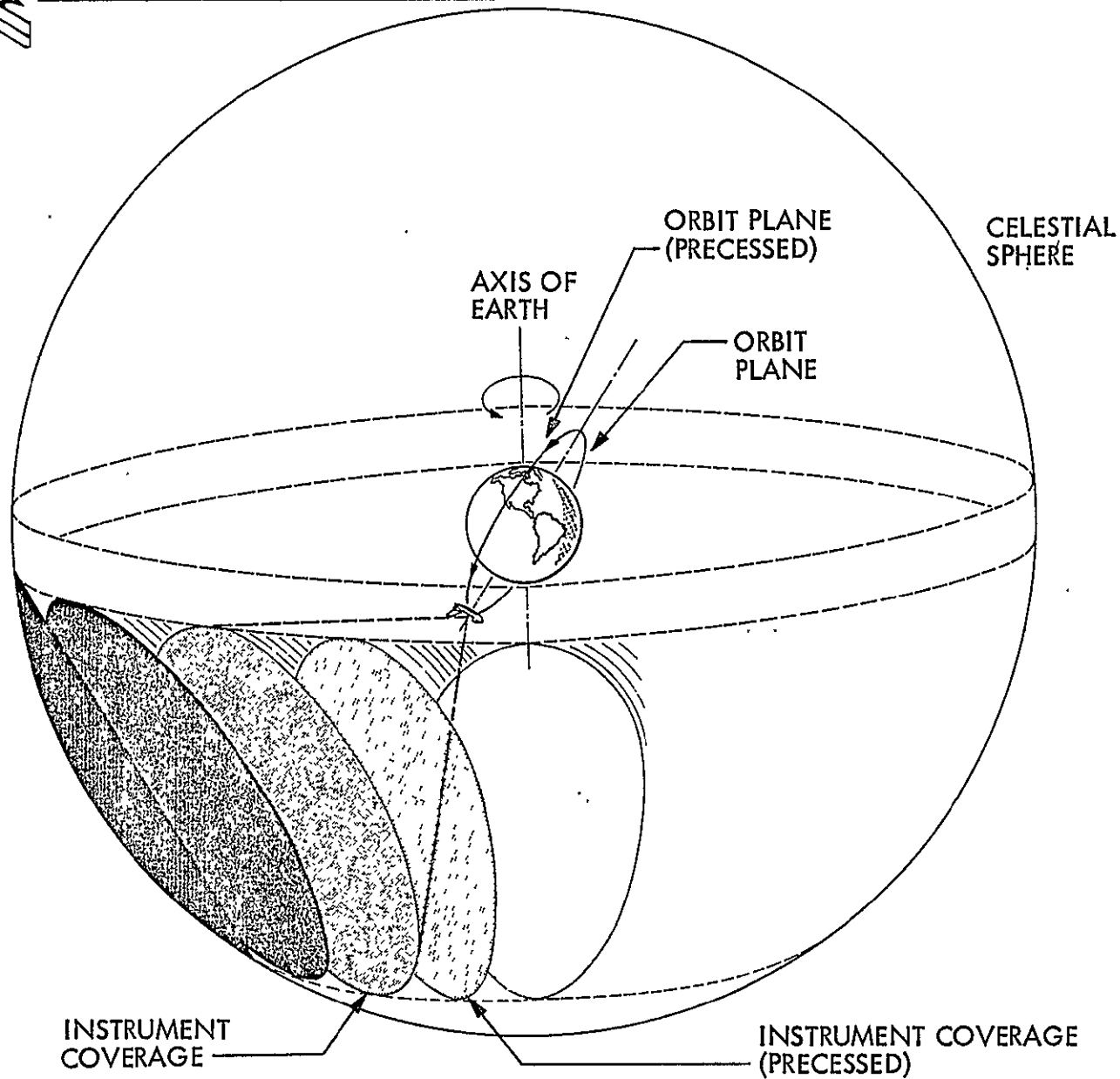


### XPOP STELLAR VIEWING GEOMETRY

- This chart shows pictorially the coverage obtainable in the XPOP orientation and how the coverage moves as the orbit precesses. The chart shows only one of the viewing areas; the other viewing opportunity is obtained by rolling the vehicle 180 degrees.



# XPOP STELLAR VIEWING GEOMETRY

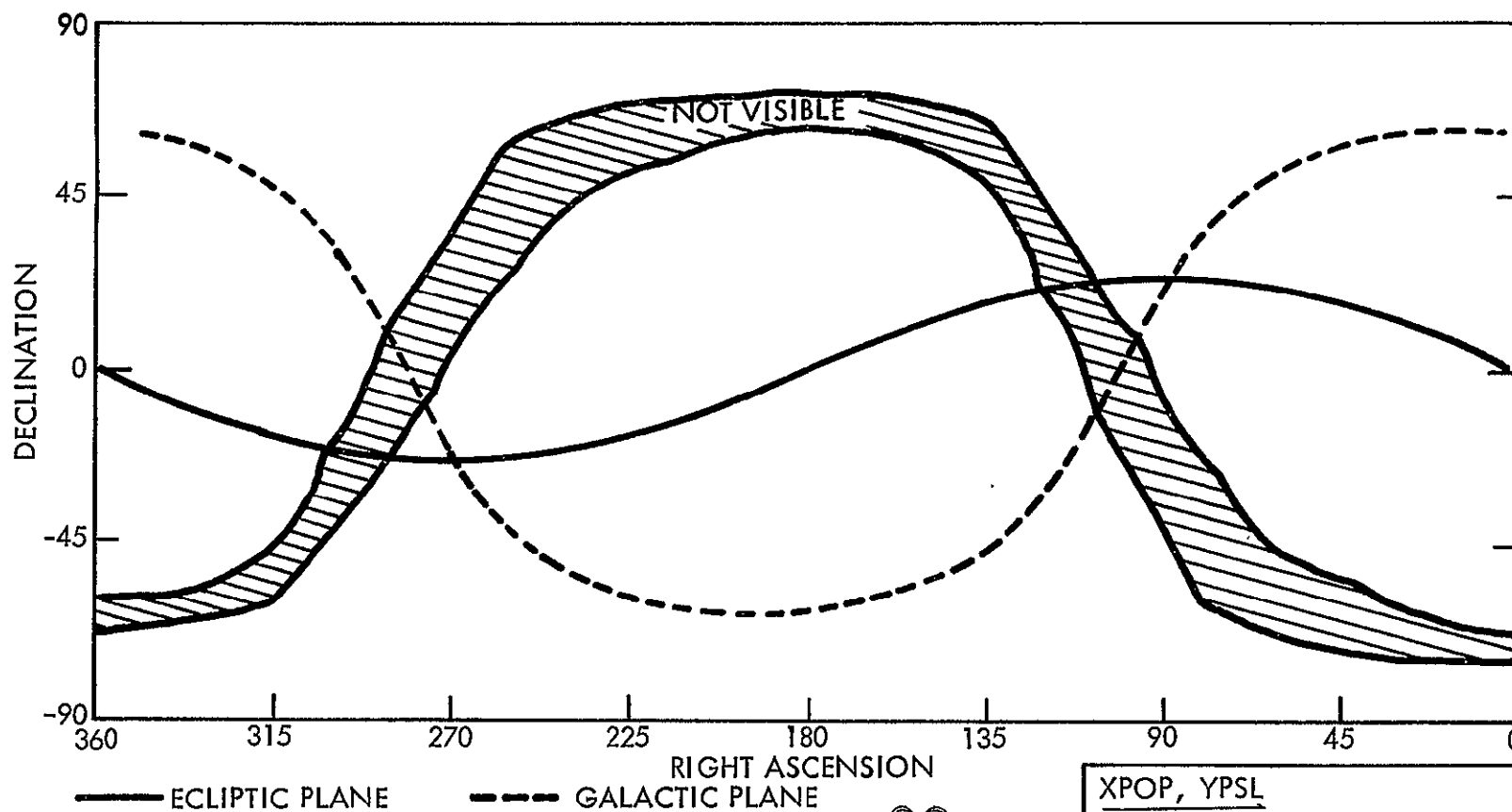


### XPOP STELLAR VIEWING COVERAGE

- This chart shows, for a specific orbit and viewing capability, the coverage of the celestial sphere available in 30 days in an XPOP, YPSL attitude.

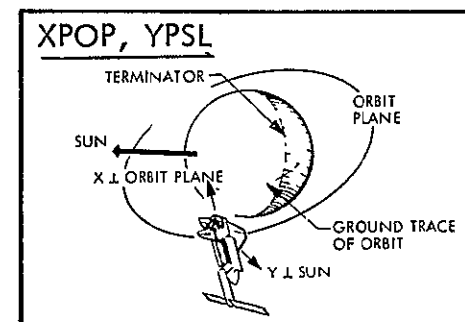


# XPOP STELLAR VIEWING COVERAGE



- LAUNCH FIRST DAY OF SPRING
- 50° INCLINATION
- 30 DAY MISSION
- VIEWING HALF ANGLE - 60°

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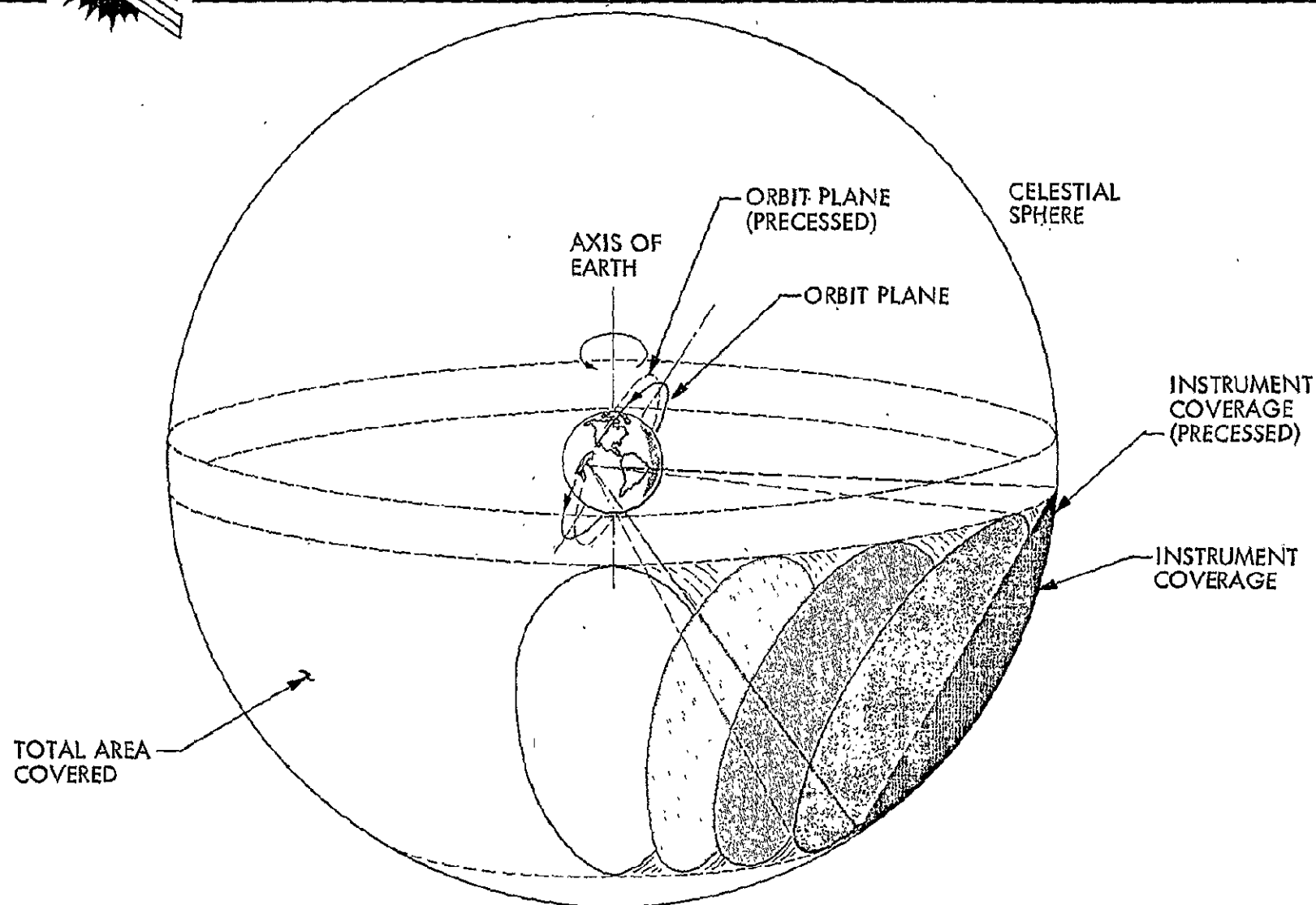
### ZPOP STELLAR VIEWING GEOMETRY

- This chart, and the chart following, show the coverage obtainable in a ZPOP, YPSL attitude.
- With the orbit and viewing coverage assumed, regions of continuous viewing (i.e., free of earth occultation) are found.



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## ZPOP STELLAR VIEWING GEOMETRY

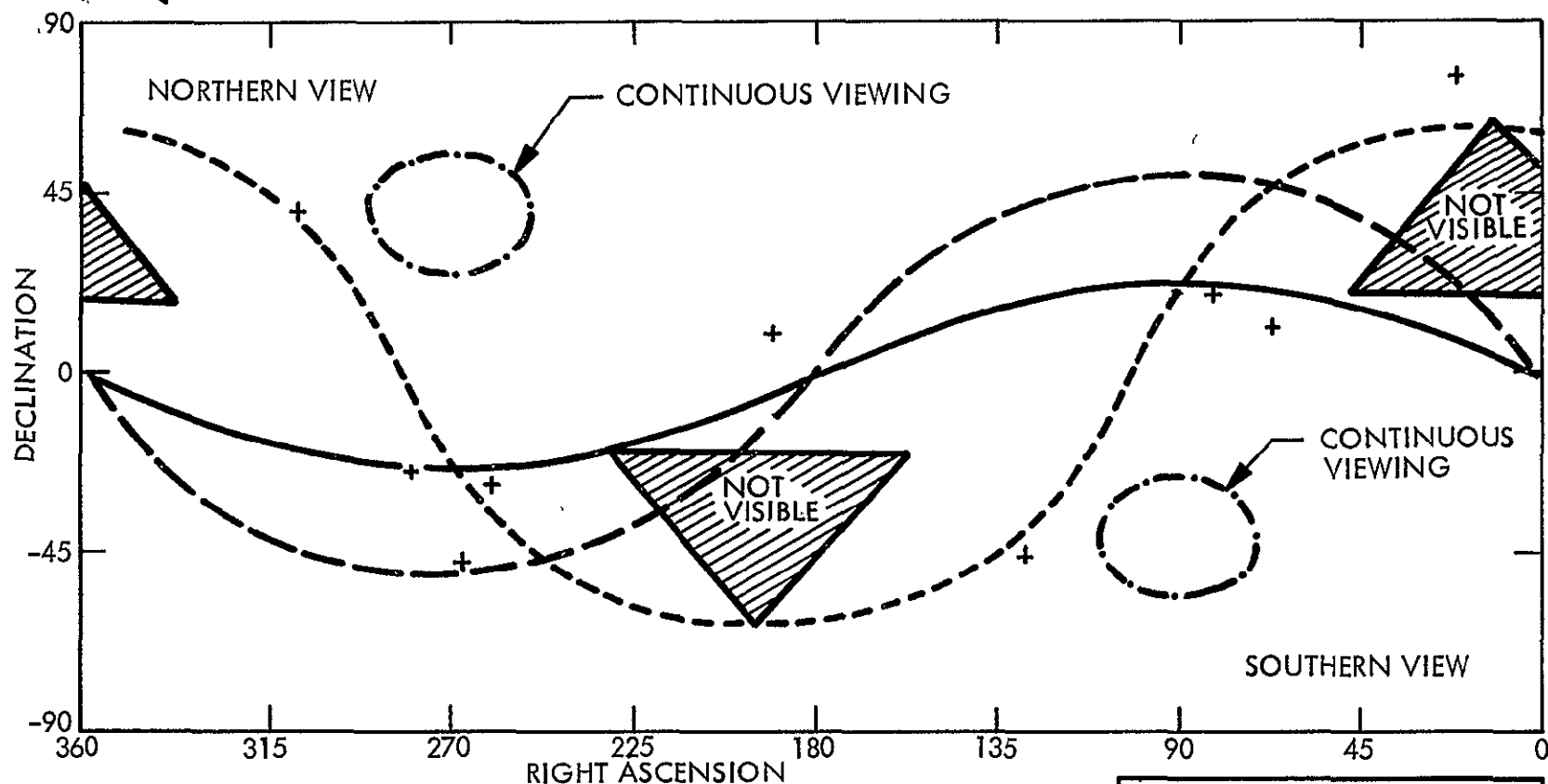


### ZPOP STELLAR VIEWING COVERAGE

- Refer to comments with previous chart.



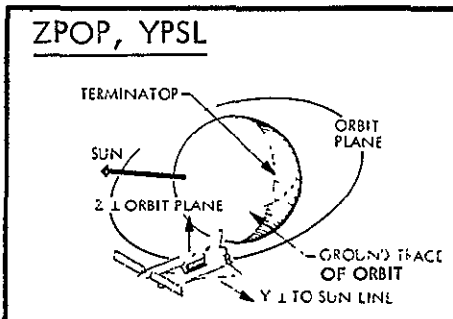
# ZPOP STELLAR VIEWING COVERAGE



— ECLIPTIC PLANE  
 --- ORBIT PLANE  
 -.- GALACTIC PLANE

RIGHT ASCENSION

- LAUNCH FIRST DAY OF SPRING
- $50^\circ$  INCLINATION
- VIEWING HALF ANGLE -  $60^\circ$
- 30 DAY MISSION
- 235 NM ALTITUDE
- $45^\circ$  SOLAR AVOIDANCE



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#### VIEWING CONDITIONS

- This chart sets out the conditions used in a viewing opportunities computer program to determine when targets can be viewed.
- The term "star latitude" is used here to represent the declination of the star relative to the orbit plane. Star longitude is the angle, measured in the orbit plane, between the projection of the sun line and the projection of the star line.

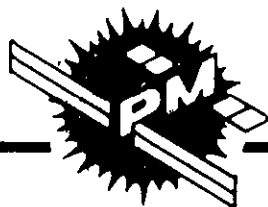


## VIEWING CONDITIONS

- XPOP, YPSL ORIENTATION
  - STAR LATITUDE  $\leq 60^\circ$
  - STAR LONGITUDE  $-60$  TO  $60$ ,  $120$  TO  $180$ ,  
OR  $-180$  TO  $-120$  } – INSTRUMENT POINTING  
LIMITATION
  - SUN-STAR ANGLE  $\geq 45^\circ$  – INSTRUMENT LIMITATION
- ZPOP, YPSL ORIENTATION
  - STAR LATITUDE  $\geq 30^\circ$  – INSTRUMENT POINTING LIMITATION
  - SUN-STAR ANGLE  $\geq 45^\circ$  – INSTRUMENT LIMITATION
  - CONTINUOUS VIEWING IF STAR LATITUDE  $\geq 70^\circ$  – ORBITAL CONSTRAINT
- ZSI, XIOP ORIENTATION
  - POWER OUTPUT = 25 kW – VEHICLE CONSTRAINT
  - SUN-STAR ANGLE  $\geq 45^\circ$  – INSTRUMENT LIMITATION
  - CONTINUOUS VIEWING IF STAR LATITUDE  $\geq 70^\circ$  – ORBITAL CONSTRAINT

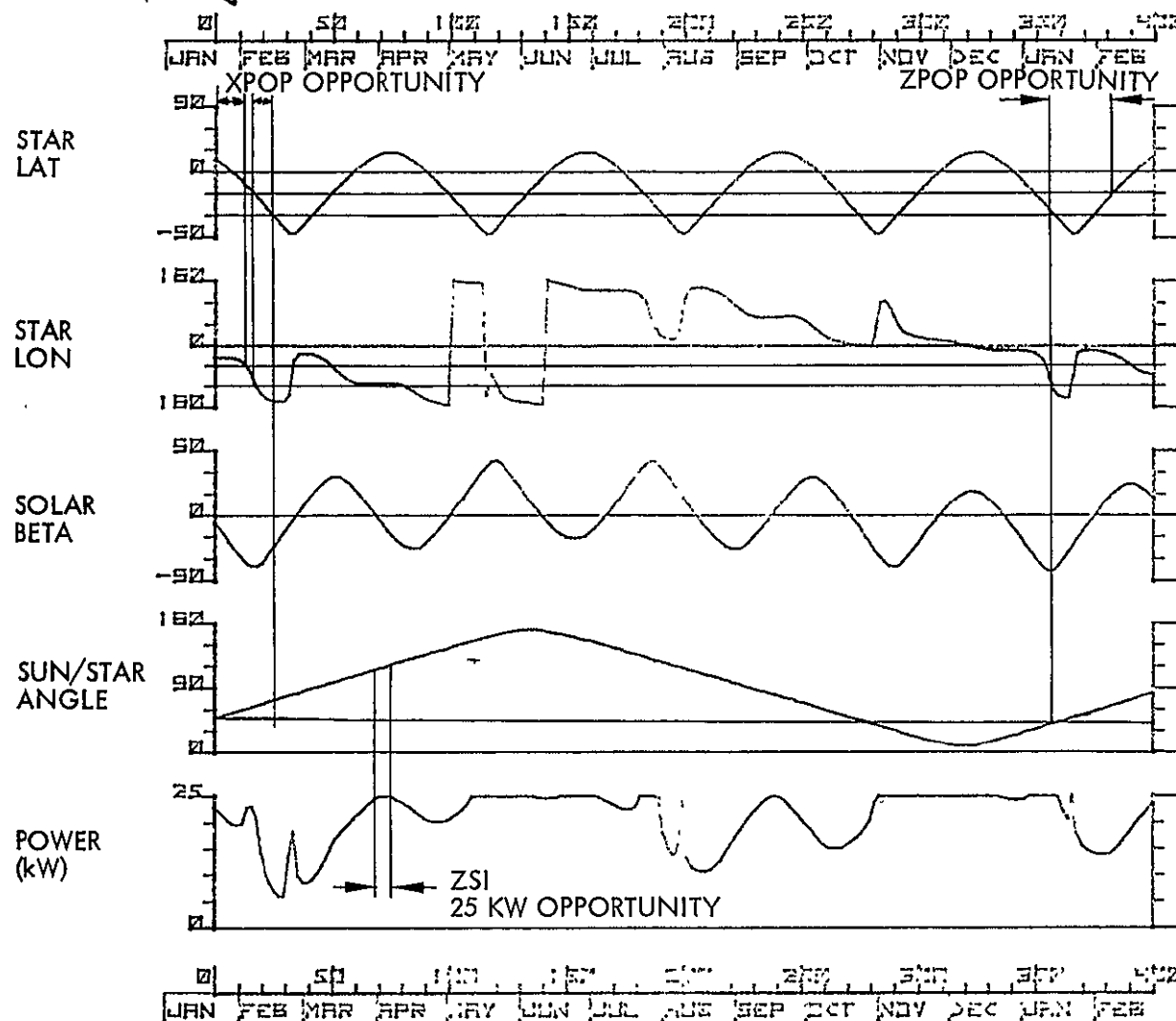
### STELLAR VIEWING CONDITIONS

- The chart shows the variation over the year of the significant viewing parameters for a specified target.
- Viewing opportunities are shown for each of the viewing modes.



# STELLAR VIEWING CONDITIONS

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TARGET STAR:  
GALACTIC CENTER

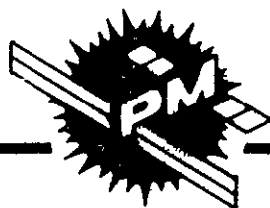
ORBIT:  
ALT 235 NM  
INCL 57°  
LON ASC NODE 0.93°  
RT ASC NODE -57.23°

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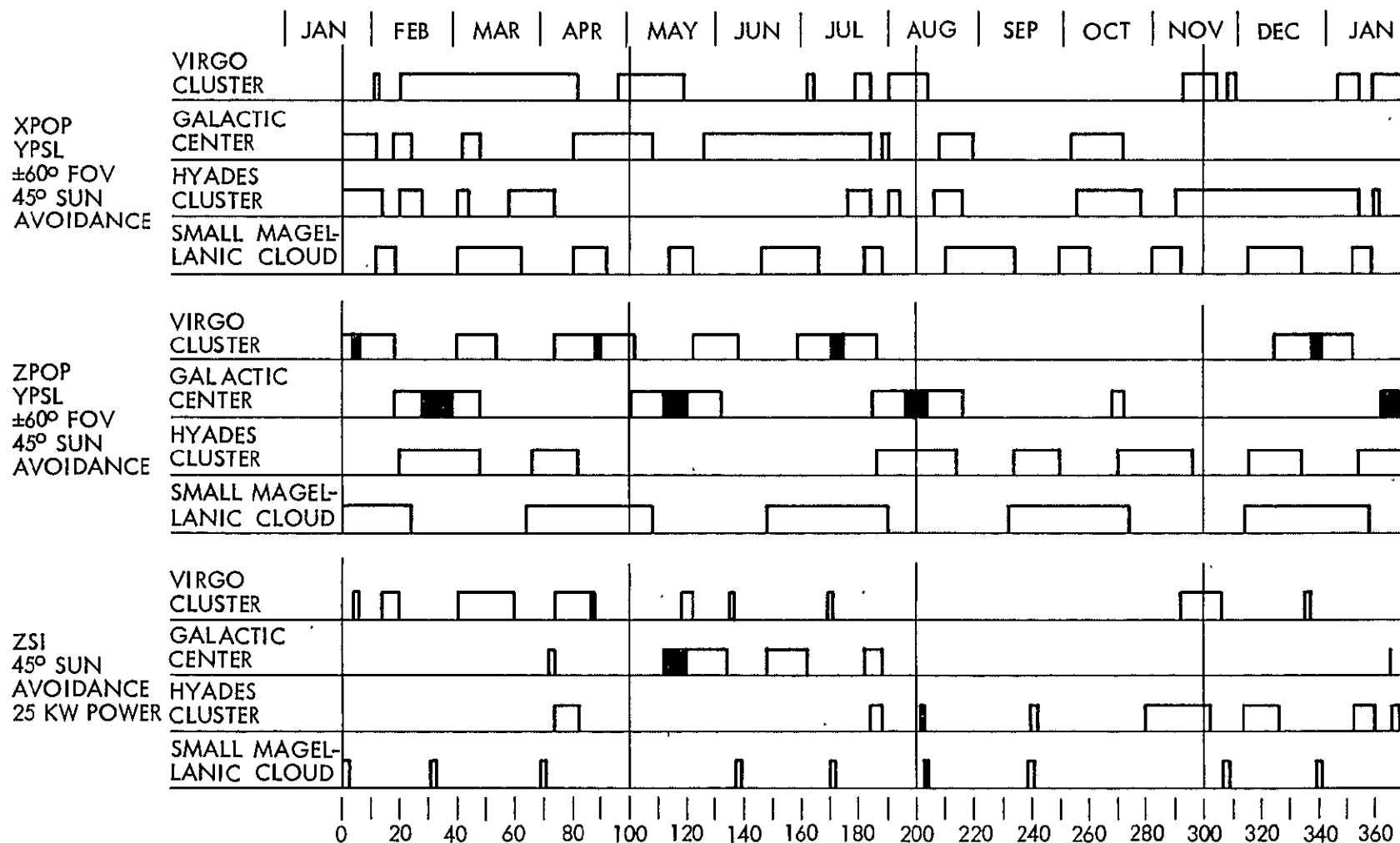
VIEWING OPPORTUNITIES: 57.0° ORBIT

- On this and the next following chart, the combined viewing opportunities are shown for all of the targets over the period of a year. The two charts present these data for both the 57.0 and 28.5° orbits.



# VIEWING OPPORTUNITIES: 57.0° ORBIT

ORBIT INCLINATION = 57.0 DEG



\* SHADED AREAS REPRESENT CONTINUOUS VIEWING OPPORTUNITIES

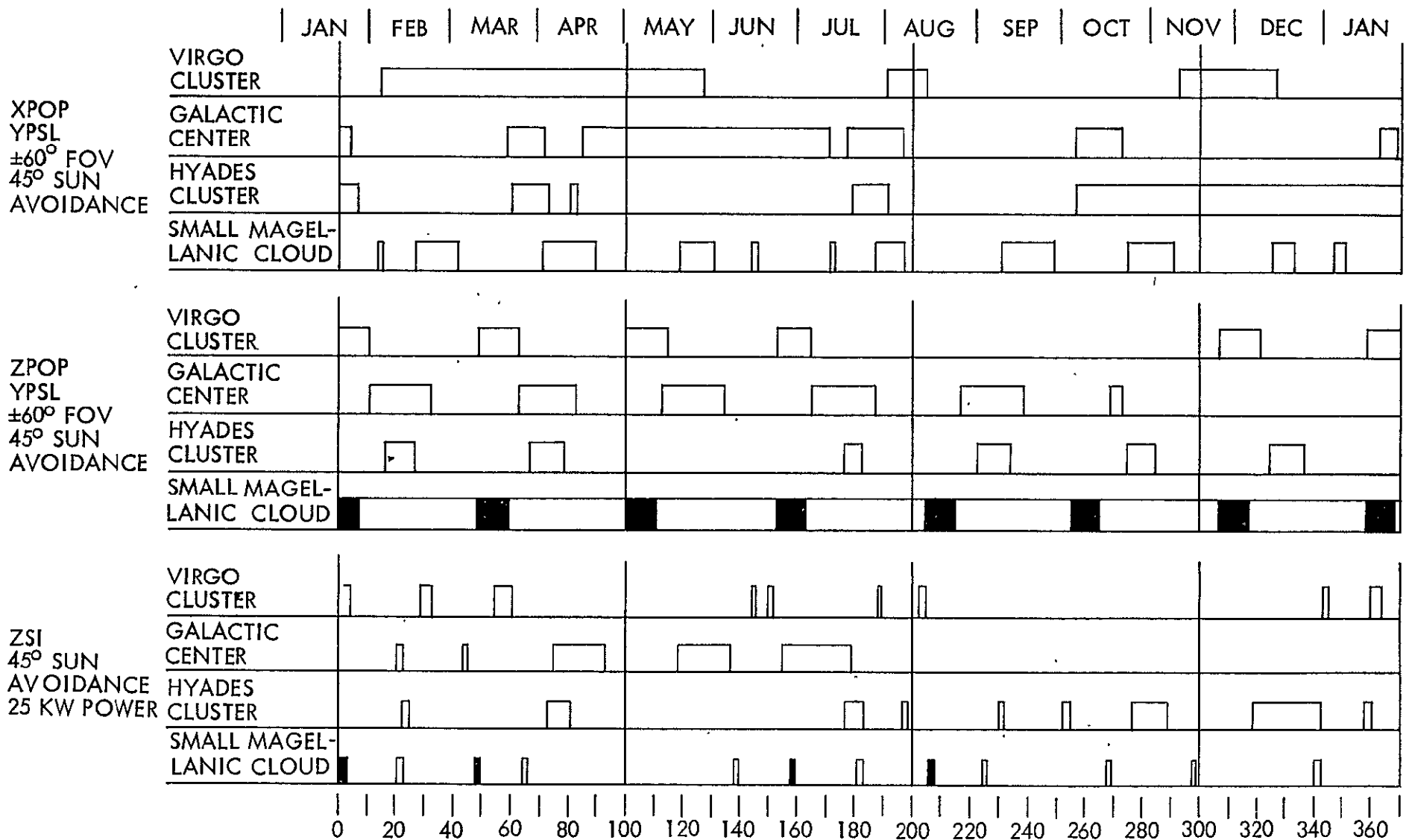
VIEWING OPPORTUNITIES:  $28.5^{\circ}$  ORBIT

- Refer to discussion with the preceding chart.



# VIEWING OPPORTUNITIES: 28.5° ORBIT

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\* SHADED AREAS REPRESENT OPPORTUNITIES FOR CONTINUOUS VIEWING



## CAPABILITIES FOR STELLAR OBSERVATION SORTIE MISSIONS

- The next six charts present data on vehicle performance in the three attitude modes. Briefly summarized, the data are as follows:
  - XPOP and ZPOP attitudes provide 25 kW at all values of beta.
  - Power generation in the ZSI attitude varies with beta and star location.
  - Heat rejection is adequate in both sortie and free flyer modes.
  - Attitude control limits attitude mode selection in the sortie mode. Only the XPOP attitude can be sustained by a three CMG ACS. Cyclical torques would require four CMGS for XPOP holding and five CMGS + desaturation once/orbit for ZSI holding.
  - As a free flyer, the three CMG ACS can handle XPOP and ZPOP orientations. A ZSI orientation would require desaturation after 150 minutes. All free flyer operations will require adding an attitude sensor to the minimum vehicle.



# CAPABILITIES FOR STELLAR OBSERVATION SORTIE MISSIONS

LMSC-D614944-5

|                                 | (XPOP, YPSL)<br><u>ATTITUDE</u>                                                       | (ZPOP, YPSL)<br><u>ATTITUDE</u>                                                             |
|---------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| <u>POWER TO ORBITER/PAYLOAD</u> | 25 kW – ALL BETAS                                                                     | 25 kW – ALL BETAS                                                                           |
| <u>TOTAL HEAT REJECTION</u>     | 54 kW – HIGH BETA<br>42.5 kW – LOW BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE   | 54 kW – LOW BETA<br>34.5 kW – HIGH BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE         |
| <u>ATTITUDE HOLDING</u>         | NO BIAS TORQUES,<br>LOW CYCLICAL<br>TORQUES, DOES NOT<br>LIMIT MISSION<br>PERFORMANCE | NO BIAS TORQUES,<br>CYCLICAL TORQUES LIMIT<br>ATTITUDE HOLDING TO<br>8.5 MINUTES(3 CMG ACS) |



# CAPABILITIES FOR STELLAR OBSERVATION

## SORTIE MISSIONS: POWER

(XIOP, ZSI ATTITUDE)

POWER TO OBITER/PAYLOAD (KW)

| PITCH<br>FROM<br>XPSL | ROLL FROM ZIOP     |     |     | ROLL FROM ZIOP     |     |     | ROLL FROM ZIOP     |     |     |
|-----------------------|--------------------|-----|-----|--------------------|-----|-----|--------------------|-----|-----|
|                       | 0°                 | 45° | 90° | 0°                 | 45° | 90° | 0°                 | 45° | 95° |
|                       | $\beta = 0^\circ$  |     |     | $\beta = 20^\circ$ |     |     | $\beta = 40^\circ$ |     |     |
| 0°                    | 25                 | 20  | 0   | 24                 | 23  | 7   | 20                 | 25  | 17  |
| 45°                   | 25                 | 21  | 17  | 24                 | 25  | 19  | 20                 | 25  | 22  |
| 90°                   | 25                 | 25  | 25  | 24                 | 25  | 25  | 20                 | 24  | 25  |
| 135°                  | 25                 | 21  | 17  | 24                 | 17  | 19  | 20                 | 15  | 22  |
| 180°                  | 25                 | 17  | 0   | 24                 | 10  | 7   | 20                 | 0   | 17  |
|                       | $\beta = 60^\circ$ |     |     | $\beta = 80^\circ$ |     |     |                    |     |     |
| 0°                    | 15                 | 25  | 25  | 6                  | 22  | 25  |                    |     |     |
| 45°                   | 15                 | 25  | 25  | 6                  | 25  | 25  |                    |     |     |
| 90°                   | 15                 | 25  | 25  | 6                  | 25  | 25  |                    |     |     |
| 135°                  | 15                 | 15  | 25  | 6                  | 25  | 25  |                    |     |     |
| 180°                  | 15                 | 7   | 25  | 6                  | 23  | 25  |                    |     |     |



# CAPABILITIES FOR STELLAR OBSERVATION SORTIE MISSIONS: HEAT REJECTION

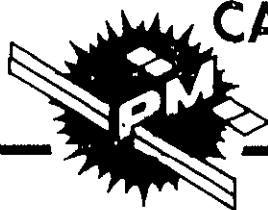
(XIOP, ZSI ATTITUDE)

| <u>TOTAL HEAT REJECTION</u> |               | <u>kW</u> |
|-----------------------------|---------------|-----------|
| LOW BETA                    | 0° PITCH/ROLL | 42.5      |
|                             | 90° ROLL      | 51.6      |
|                             | 90° PITCH     | 54.1      |
| HIGH BETA                   | 0° ROLL/YAW   | 34.5      |
|                             | +90° ROLL     | 34.5      |
|                             | -90° ROLL     | 41.5      |
|                             | 90° YAW       | 34.5      |

DOES NOT LIMIT MISSION PERFORMANCE

## ATTITUDE HOLDING

BIAS + CYCLICAL TORQUES. RESTRICT HOLD TIME TO 8.2 – 8.6  
MINUTES (3 CMG ACS)

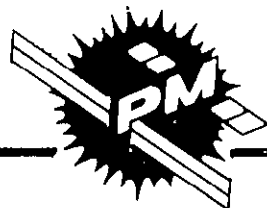


# CAPABILITIES FOR STELLAR OBSERVATION FREE-FLYER MISSIONS

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|                             | <u>XPOP, YPSL<br/>ATTITUDE</u>                                                          | <u>ZPOP, YPSL<br/>ATTITUDE</u>                                                        |
|-----------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <u>POWER TO PAYLOAD</u>     | 25 kW — ALL BETAS                                                                       | 25 kW — ALL BETAS                                                                     |
| <u>TOTAL HEAT REJECTION</u> | 22.4 kW — HIGH BETA<br>18.7 kW — LOW BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE   | 22.4 kW — LOW BETA<br>16.3 kW — HIGH BETA<br>DOES NOT LIMIT<br>MISSION<br>PERFORMANCE |
| <u>ATTITUDE HOLDING</u>     | NO BIAS TORQUES<br>LOW CYCLICAL<br>TORQUES<br><br>3CMG'S ADEQUATE FOR<br>LONG TERM HOLD | NO BIAS TORQUES<br>CYCLICAL TORQUES<br>WITHIN CAPABILITY OF 3CMG ACS                  |
| <u>ATTITUDE REFERENCE</u>   | 0.5 DEG ACCURACY*                                                                       | 0.5 DEG ACCURACY*                                                                     |

\*EQUIVALENT TO ORBITER ACCURACY



# CAPABILITIES FOR STELLAR OBSERVATION FREE-FLYER MISSIONS: POWER

(XIOP, ZSI ATTITUDE)

POWER TO PAYLOAD (KW)

| PITCH<br>FROM<br>XPSL | ROLL FROM ZIOP     |     |     | ROLL FROM ZIOP     |     |     | ROLL FROM ZIOP     |     |     |
|-----------------------|--------------------|-----|-----|--------------------|-----|-----|--------------------|-----|-----|
|                       | 0°                 | 45° | 90° | 0°                 | 45° | 90° | 0°                 | 45° | 95° |
|                       | $\beta = 0^\circ$  |     |     | $\beta = 20^\circ$ |     |     | $\beta = 40^\circ$ |     |     |
| 0°                    | 25                 | 20  | 0   | 24                 | 23  | 7   | 20                 | 25  | 17  |
| 45°                   | 25                 | 21  | 17  | 24                 | 25  | 19  | 20                 | 25  | 22  |
| 90°                   | 25                 | 25  | 25  | 24                 | 25  | 25  | 20                 | 24  | 25  |
| 135°                  | 25                 | 21  | 17  | 24                 | 17  | 19  | 20                 | 15  | 22  |
| 180°                  | 25                 | 17  | 0   | 24                 | 10  | 7   | 20                 | 0   | 17  |
|                       | $\beta = 60^\circ$ |     |     | $\beta = 80^\circ$ |     |     |                    |     |     |
| 0°                    | 15                 | 25  | 25  | 6                  | 22  | 25  |                    |     |     |
| 45°                   | 15                 | 25  | 25  | 6                  | 25  | 25  |                    |     |     |
| 90°                   | 15                 | 25  | 25  | 6                  | 25  | 25  |                    |     |     |
| 135°                  | 15                 | 15  | 25  | 6                  | 25  | 25  |                    |     |     |
| 180°                  | 15                 | 7   | 25  | 6                  | 23  | 25  |                    |     |     |

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# CAPABILITIES FOR STELLAR OBSERVATION FREE-FLYER MISSIONS: HEAT REJECTION

(XIOP, ZSI ATTITUDE)

| <u>TOTAL HEAT REJECTION</u> |               | <u>KW</u> |
|-----------------------------|---------------|-----------|
| LOW BETA                    | 0° PITCH/ROLL | 18.7      |
|                             | 90° ROLL      | 20.6      |
|                             | 90° PITCH     | 22.4      |
| HIGH BETA                   | 0° ROLL/YAW   | 16.3      |
|                             | +90° ROLL     | 16.3      |
|                             | -90° ROLL     | 20.6      |
|                             | 90° YAW       | 16.3      |

DOES NOT LIMIT MISSION PERFORMANCE

## ATTITUDE HOLDING

BIAS + CYCLICAL TORQUES, DESATURATION REQUIRED AFTER 150 MIN (3CMG ACS)

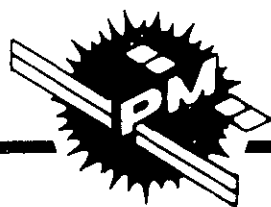
## ATTITUDE REFERENCE

ORBITER ACCURACY REQUIRED (.5 DEG  $3\sigma$ )



STELLAR VIEWING OPPORTUNITY SUMMARY  
57° ORBIT SORTIE

- Viewing opportunities data and vehicle capabilities data were combined to show the viewing capabilities of the various vehicle variations. This, and the next following chart present data for the sortie mode in both 57 and 28° orbits. Note that the minimum sortie vehicle provides very substantial viewing capability and that addition of a fourth CMG permits exploitation of the continuous viewing opportunities that orbit mechanics permit.
- The 4 CMG capability is available from a minimum free flyer, with attitude sensor.



# STELLAR VIEWING OPPORTUNITY SUMMARY 57° ORBIT SORTIE

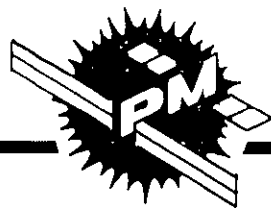
DAYS TARGET VIEWABLE - 1 YEAR INTERVAL

| TARGET                 | MINIMUM - 25 KW  |                    | 4CMG'S - 25 KW   |                    | 5CMG'S + DESAT - 25 kW |                    | 5CMG'S + DESAT - 20 kW |                    |
|------------------------|------------------|--------------------|------------------|--------------------|------------------------|--------------------|------------------------|--------------------|
|                        | OCCULTED VIEWING | CONTINUOUS VIEWING | OCCULTED VIEWING | CONTINUOUS VIEWING | OCCULTED VIEWING       | CONTINUOUS VIEWING | OCCULTED VIEWING       | CONTINUOUS VIEWING |
| VIRGO CLUSTER          | 145              | 0                  | 235              | 14                 | 241                    | 14                 | 279                    | 14                 |
| GALACTIC CENTER        | 151              | 0                  | 208              | 34                 | 211                    | 34                 | 275                    | 34                 |
| HYADES CLUSTER         | 161              | 0                  | 236              | 0                  | 237                    | 0                  | 273                    | 0                  |
| SMALL MAGELLANIC CLOUD | 162              | 0                  | 267              | 0                  | 276                    | 0                  | 357                    | 0                  |

STELLAR VIEWING OPPORTUNITY SUMMARY

28<sup>0</sup> ORBIT SORTIE

- Refer to discussion with preceding chart.



# STELLAR VIEWING OPPORTUNITY SUMMARY

## 28° ORBIT SORTIE

DAYS TARGET VIEWABLE - ONE YEAR INTERVAL

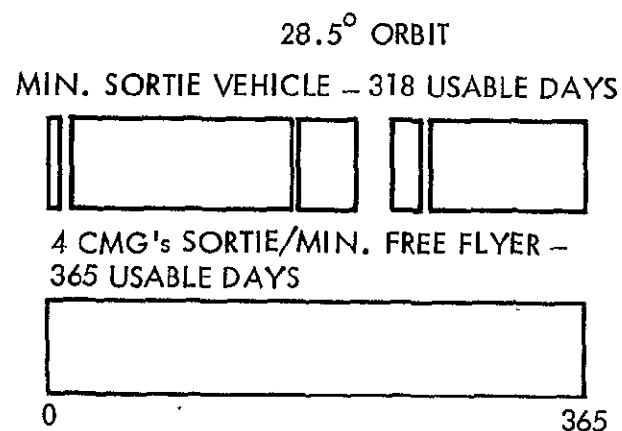
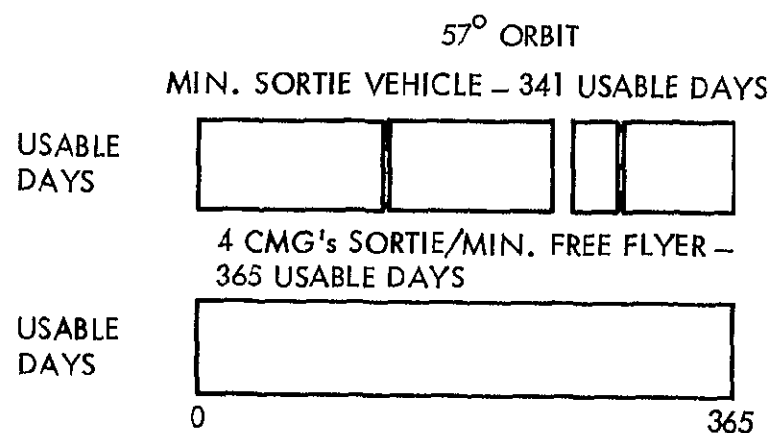
| TARGET                 | MINIMUM - 25 kW  |                    | 4CMG'S - 25 kW   |                    | 5CMG'S + DESAT - 25 kW |                    | 5CMG'S + DESAT - 20 kW |                    |
|------------------------|------------------|--------------------|------------------|--------------------|------------------------|--------------------|------------------------|--------------------|
|                        | OCCULTED VIEWING | CONTINUOUS VIEWING | OCCULTED VIEWING | CONTINUOUS VIEWING | OCCULTED VIEWING       | CONTINUOUS VIEWING | OCCULTED VIEWING       | CONTINUOUS VIEWING |
| VIRGO CLUSTER          | 163              | 0                  | 194              | 0                  | 201                    | 0                  | 279                    | 0                  |
| GALACTIC CENTER        | 147              | 0                  | 213              | 0                  | 215                    | 0                  | 266                    | 0                  |
| HYADES CLUSTER         | 146              | 0                  | 178              | 0                  | 185                    | 0                  | 273                    | 0                  |
| SMALL MAGELLANIC CLOUD | 113              | 0                  | 365              | 81                 | 365                    | 81                 | 365                    | 81                 |

## STELLAR OBSERVATION MISSION EVALUATION

- To provide a measure of overall capability, the usable experiment days were plotted over the period of a year. It was assumed that a day was usable if any one of the four target areas could be observed.
- It was found that, with the minimum vehicle in a sortie mission, 318 and 341 days in the year were usable in a 28.5 and 57.0° orbits, respectively. With the minimum free flyer, every day is usable in either 28.5 or 57 degree orbit.
- It is concluded that missions can readily be scheduled permitting effective experimental exploitation of the mission duration provided by the power module.



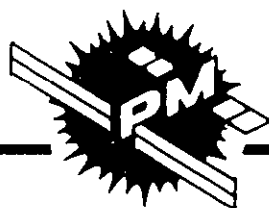
## STELLAR OBSERVATION MISSION EVALUATION



CONCLUSION: PROPER SCHEDULING PERMITS 100% USABLE MISSION TIME  
WITH MINIMUM POWER MODULE, 28.5° OR 57° ORBIT

#### STELLAR OBSERVATION MISSION ACCOMMODATION SUMMARY OF FINDINGS

- The findings of the analysis confirm the capability of the power module to support stellar viewing missions; both sortie and free flyer.



# STELLAR OBSERVATION MISSION ACCOMMODATION

LMSC-D614944-5

## SUMMARY OF FINDINGS

### SORTIE MODE

- MINIMUM POWER MODULE VEHICLE CAN PERFORM MISSION IN  $28.5^\circ$  OR  $57^\circ$  ORBIT (REQUIRES EXPERIMENT AIMING PACKAGE). EFFECTIVE 30-DAY MISSIONS CAN READILY BE SCHEDULED.
- FOUR CMGs IN POWER MODULE PERMIT EXPLOITATION OF CONTINUOUS VIEWING OPPORTUNITIES (LIMITED BY ORBIT GEOMETRY). TOTAL FLIGHT-TIME CAN BE UTILIZED.
- FIVE CMGs + DESATURATION IN POWER MODULE PROVIDES ALTERNATIVE TO EXPERIMENT AIMING PACKAGE.

### FREE-FLYER MODE

- FREE-FLYER POWER MODULE WITH MINIMUM ACS + ATTITUDE REFERENCE CAN PERFORM MISSION IN  $28.5^\circ$  OR  $57^\circ$  ORBIT. TOTAL FLIGHT-TIME AND CONTINUOUS VIEWING CAPABILITIES CAN BE EXPLOITED.
- ADDITION OF DESATURATION CAPABILITY PROVIDES ALTERNATIVE TO EXPERIMENT AIMING PACKAGE.



### 3.4 ACCOMMODATIONS SUMMARY

#### MISSION ACCOMMODATION ANALYSIS SUMMARY OF FINDINGS

- The results of the study effort are briefly summarized here. For the three types of missions examined, it is our finding that the minimum power module provides a substantial mission support capability on sortie flights. Addition of an attitude sensor is required for free-flyer pointing missions.



# MISSION ACCOMMODATION ANALYSIS

## SUMMARY OF FINDINGS

### STO

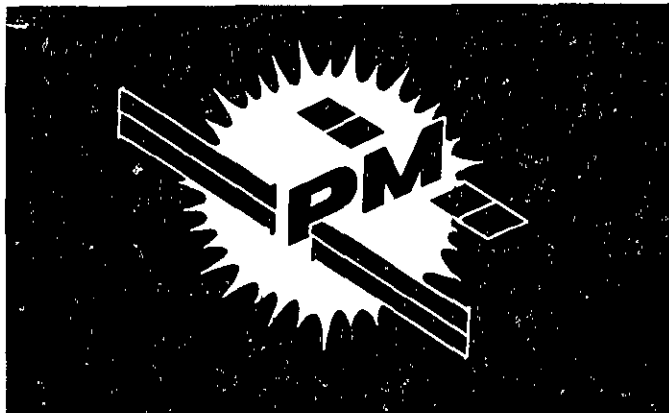
- MINIMUM POWER MODULE ACCOMMODATES MISSION IN SORTIE MODE
  - EXPERIMENT TIME-LINING REQUIRED TO VERIFY POWER REQUIREMENTS
  - INCREASED SIMULTANEOUS SUN-NADIR VIEWING REQUIREMENTS COULD NECESSITATE ONE ADDITIONAL CMG OR CHANGE TO SOLAR ARRAY
- ADDITION OF ATTITUDE SENSOR TO MINIMUM POWER MODULE ACCOMMODATES MISSION IN FREE-FLYER MODE

### MATERIALS PROCESSING/LIFE SCIENCE

- MINIMUM POWER MODULE SATISFIES MISSION REQUIREMENTS IN SORTIE MODE
- MINIMUM POWER MODULE ACCOMMODATES MISSION AS FREE-FLYER IN GRAVITY GRADIENT MODE
  - AVAILABLE POWER AT  $\text{BETA} = 40^\circ$  LIMITED TO 21 kW UNLESS ATTITUDE SENSOR ADDED OR ARRAY SECOND DEGREE OF FREEDOM PROVIDED.

### STELLAR OBSERVATION

- MINIMUM VEHICLE ACCOMMODATES SORTIE MISSION
  - ADDITION OF 1 CMG PERMITS EXPLOITATION OF CONTINUOUS VIEWING OPPORTUNITIES
  - ADDITION OF 2 CMGs AND DESATURATION AN ALTERNATIVE TO WIDE FIELD EXPERIMENT AIMING PACKAGE
- ADDITION OF ATTITUDE SENSOR TO MINIMUM POWER MODULE ACCOMMODATES FREE-FLYER MISSION



## SECTION 4 CONCLUSIONS AND RECOMMENDATIONS

PRECEDING PAGE  
BEARING INFORMATION

## POWER MODULE DESIGN RECOMMENDATIONS

- The minimum vehicle satisfies all requirements, except that in the free flyer mode, attitude sensors are required for pointing missions. The minimum vehicle is functionally equivalent to the MSFC Phase A baseline.
- Several added benefits are identified on the chart accruing from augmentations to the attitude control system.
- These recommendations are inputs to Parts II and III of the overall study.



# POWER MODULE DESIGN RECOMMENDATIONS

---

## SORTIE MODE

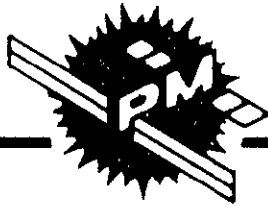
- MINIMUM VEHICLE SATISFIES ALL REQUIREMENTS.
- SINGLE CMG ADDITION WOULD INCREASE SUN-NADIR SIMULTANEOUS VIEWING FOR STO AND PERMIT EXPLOITATION OF CONTINUOUS STELLAR VIEWING OPPORTUNITIES.
- TWO ADDITIONAL CMGs PLUS DESATURATION CAPABILITY WOULD SUPPORT NON-GIMBALLED STELLAR PAYLOADS.

## FREE-FLYER MODE

- MINIMUM VEHICLE SUPPORTS MPS/LIFE-SCIENCE MISSIONS.
- ATTITUDE SENSOR ADDITION IS REQUIRED FOR POINTING MISSIONS.

## POWER MODULE PERFORMANCE CONTRIBUTIONS

- The chart summarizes the primary system performance gains provided by the Power Module as identified in the course of the mission accommodation analysis.



## POWER MODULE PERFORMANCE CONTRIBUTIONS

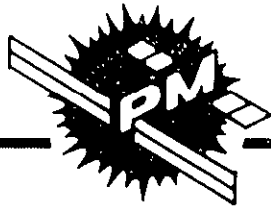
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- MISSION DURATION: INCREASE ORBITER SORTIE FROM 5 TO 30-60 DAYS  
IN PM LONG DURATION MODE: 17 DAYS IN HIGH POWER MODE: PAY-  
LOAD LIMITED AS FREE FLYER
- PAYLOAD POWER: INCREASES FROM 7 kW (5 DAY SORTIE) TO 11 kW (30  
TO 60 DAY SORTIE); 19 kW IN HIGH POWER MODE; 25 kW AS FREE FLYER
- HEAT REJECTION: INCREASES FROM 0.6 TO 9.7 – 26.3 kW; ELIMINATES  
MOST ORBITER ATTITUDE RESTRICTIONS
- ATTITUDE HOLDING: ENABLES LONG-TERM HOLDING IN INERTIAL AND  
EARTH ORIENTED ATTITUDES
- CONTAMINATION CONTROL: ENABLES AVOIDANCE OF RCS/VCS AND  
FLASH-EVAPORATOR CONTAMINANTS
- G-LEVEL: ENABLES AVOIDANCE OF RCS/VCS THRUST VECTORING, PER-  
MITTING LONG-DURATION  $10^{-5}$  G OPERATIONS

#### POWER MODULE MISSION CONTRIBUTIONS

- The chart summarizes the primary benefits provided by the Power Module to each of the three missions, as identified in the course of the mission accommodation analysis.

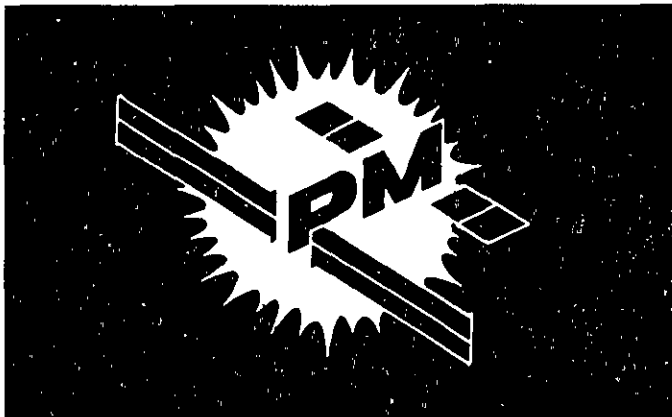




## POWER MODULE MISSION CONTRIBUTIONS

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- SOLAR TERRESTRIAL OBSERVATION: ENABLES CONTINUOUS SOLAR MONITORING
- MPS/LIFE SCIENCE: ENABLES LONG-DURATION  $10^{-5}G$  ENVIRONMENT, WITH PAYLOAD POWER UP TO  $11^{-19}$  kW (SORTIE) AND 25 kW (FREE-FLYER)
- STELLAR OBSERVATION: ENABLES LONG DURATION CONTAMINATION-FREE OBSERVATIONS

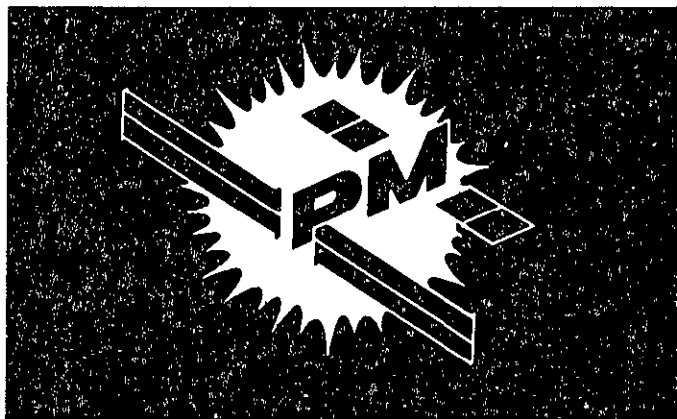


## SECTION 5 REFERENCES

PRECEDING PAGE WITH NEW DESIGN

## REFERENCES

1. Astrophysics Payloads for Spacelab, Summary Report - Shuttle Spacelab Payloads Project Office, Goddard Space Flight Center, October 1976
2. Solar Physics Payloads for Spacelab, Summary Report - Shuttle Spacelab Payloads Project Office, Goddard Space Flight Center, October 1976
3. Study of the Use of Spacelab Derived Elements Within Different Possible Steps Towards a Space Platform, Final Report, ERNO, January 1978
4. Orbital Service Module, Briefing to the Administrator, Johnson Space Flight Center, January 1978
5. TRW AMPS Payload Design, TRW Defense and Space Systems Group, June 1976
6. Orbiter Kits for Operations with Space Power Modules, Rockwell International, July 1977
7. 25 kW Power Module Preliminary Definition, George C. Marshall Space Flight Center, September 1977
8. Experiment Pointing Systems' Review, George C. Marshall Space Flight Center, February 1978
9. Orbital Service Module, Midterm Review, Executive Summary - Presented to OSTIS, NASA, Johnson Space Flight Center, July 1978
10. Orbital Service Module, Systems Analysis Study, Final Review, Johnson Space Flight Center, November 1978



## APPENDICES

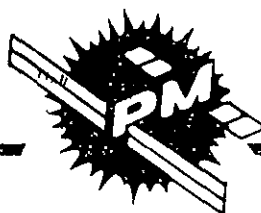
- A SYSTEM CAPABILITY DATA
- B STO SAMPLE EXPERIMENT
- C STO VIEWING ANALYSIS DATA

PRECEDING PAGES BEING LEFT BEHIND

APPENDIX A  
SYSTEM CAPABILITY DATA

INTRODUCTION

- These charts represent a compendium of vehicle capabilities in the attitude modes analyzed. (Refer to Vol. 1, Section 4 for a description of the vehicle).
- The first two charts define the power generating capability which applies to both sortie and free flyer modes. It will be noted that the Power Module array can produce more than 25 kW over a wide range of conditions if the output is not limited by power handling circuits.
- The next four charts contain data on the attitude holding capability of the vehicle.
- The following chart summarizes the attitude control capability of the free-flyer.
- The last three charts provide data on heat rejection.



LMSC-D614944-5

# CAPABILITIES FOR INERTIALLY ORIENTED MISSIONS

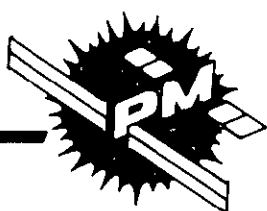
POWER TO ORBITER/PAYLOAD (kW) – MINIMUM VEHICLE

OUTPUT RESTRICTED TO 25 kW MAX

| SUN – Y AXIS<br>ANGLE (DEG) | BETA ANGLE (DEG) |    |    |    |    |    |    |    |    |
|-----------------------------|------------------|----|----|----|----|----|----|----|----|
|                             | 0                | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
| 0                           | 0                | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 10                          | 3                | 3  | 3  | 3  | 3  | 3  | 4  | 6  | 6  |
| 20                          | 7                | 7  | 7  | 8  | 8  | 9  | 10 | 15 | 15 |
| 30                          | 12               | 12 | 12 | 12 | 13 | 13 | 15 | 22 | 22 |
| 40                          | 15               | 16 | 16 | 16 | 17 | 18 | 20 | 25 | 25 |
| 50                          | 19               | 19 | 19 | 19 | 20 | 21 | 24 | 25 | 25 |
| 60                          | 21               | 22 | 22 | 22 | 23 | 24 | 25 | 25 | 25 |
| 70                          | 23               | 24 | 24 | 24 | 25 | 25 | 25 | 25 | 25 |
| 80                          | 25               | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| 90                          | 25               | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |

OUTPUT NOT RESTRICTED

| ANGLE | BETA ANGLE (DEG) |    |    |    |    |    |    |    |    |
|-------|------------------|----|----|----|----|----|----|----|----|
|       | 0                | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
| 0     | 0                | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 10    | 3                | 3  | 3  | 3  | 3  | 3  | 4  | 6  | 6  |
| 20    | 7                | 7  | 7  | 8  | 8  | 9  | 10 | 15 | 15 |
| 30    | 12               | 12 | 12 | 12 | 13 | 13 | 15 | 22 | 22 |
| 40    | 15               | 16 | 16 | 16 | 17 | 18 | 20 | 29 | 29 |
| 50    | 19               | 19 | 19 | 19 | 20 | 21 | 24 | 35 | 35 |
| 60    | 21               | 22 | 22 | 22 | 23 | 24 | 28 | 40 | 40 |
| 70    | 23               | 24 | 24 | 24 | 25 | 27 | 30 | 43 | 43 |
| 80    | 25               | 25 | 25 | 26 | 27 | 28 | 32 | 46 | 46 |
| 90    | 25               | 26 | 26 | 26 | 27 | 29 | 32 | 46 | 46 |



# CAPABILITIES FOR EARTH ORIENTED MISSIONS

LMSC-D614944-5

POWER TO ORBITER/PAYLOAD (kW) – MINIMUM VEHICLE

XPOP, ZLV  $\pm 90^\circ$  ROLL

| VIEW ANGLE<br>FROM<br>VERTICAL<br>(DEG) | BETA ANGLE (DEG) |    |    |    |    |
|-----------------------------------------|------------------|----|----|----|----|
|                                         | 0                | 20 | 40 | 60 | 80 |
| 0                                       | 12               | 16 | 21 | 25 | 25 |
| 30                                      | 14               | 17 | 22 | 25 | 25 |
| 60                                      | 16               | 19 | 23 | 25 | 25 |
| 90                                      | 16               | 19 | 23 | 25 | 25 |

XVV, ZLV  $\pm 90^\circ$  PITCH

|    |    |    |    |    |   |
|----|----|----|----|----|---|
| 0  | 25 | 24 | 20 | 15 | 6 |
| 30 | 25 | 24 | 20 | 15 | 6 |
| 60 | 25 | 24 | 20 | 15 | 6 |
| 90 | 25 | 24 | 20 | 15 | 6 |

ZLV, YPSL

|   |    |    |    |    |    |
|---|----|----|----|----|----|
| 0 | 25 | 25 | 25 | 25 | 25 |
|---|----|----|----|----|----|

XLV, ZPOP

|    |    |    |    |    |    |
|----|----|----|----|----|----|
| 90 | 12 | 16 | 21 | 25 | 25 |
|----|----|----|----|----|----|

25 kW LIMIT IMPOSED BY POWER CONTROL CIRCUITRY



# CAPABILITIES FOR EARTH ORIENTED SORTIE MISSIONS

ATTITUDE HOLDING - MINIMUM VEHICLE

X POP, ZLV  $\pm 90^\circ$  ROLL

SMALL BIAS TORQUE ABOUT X AXIS IF ROLLED. TWO ORBITS TO SATURATION AT  $45^\circ$  ROLL (3CMG ACS)

XVV, ZLV  $\pm 90^\circ$  PITCH

NO GRAVITY GRADIENT TORQUES AT  $0^\circ$  PITCH OR  $90^\circ$  PITCH. LARGE GRAVITY GRADIENT TORQUES IF PITCHED. FIVE MINUTES TO CMG SATURATION AT  $45^\circ$  PITCH (3 CMG ACS)

ZLV, YPSL

APPARENT LARGE TORQUES - CROSS COUPLING OF YAW AND ROTATION AT ORBITAL RATE

XLV, ZPOP

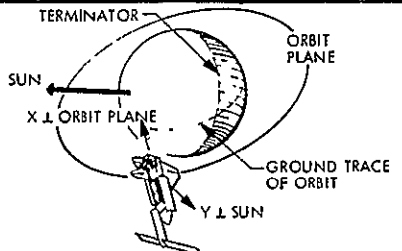
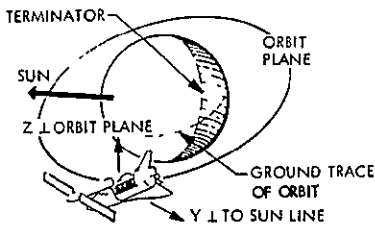
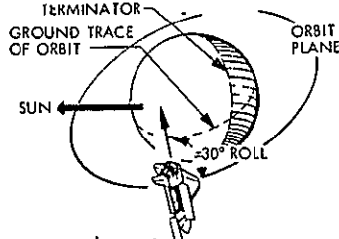
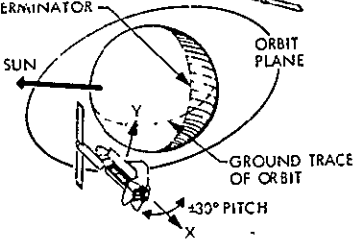
NO GRAVITY GRADIENT TORQUES



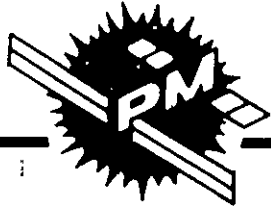


# ATTITUDE HOLDING CAPABILITY INERTIAL SORTIE POINTING MODES

LMSC-D614944-5

| MODES                                                                                                                                       | CONDITIONS                                                                                                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><u>XPOP, YPSL</u></p>                                  | <p>NO BIAS TORQUES, SMALL CYCLIC TORQUES.<br/>3 CMG'S ADEQUATE FOR LONG TERM HOLD</p>                                                                           |
| <p><u>ZPOP, YPSL</u></p>                                  | <p>NO BIAS TORQUES, CYCLIC TORQUES LIMIT<br/>HOLD TIME TO 8.5 MIN. (3 CMG ACS) 4 CMG<br/>ACS ADEQUATE FOR LONG TERM HOLDING</p>                                 |
| <p><u>XPOP, YPSL <math>\pm 30^\circ</math> ROLL</u></p>  | <p>IF NOT PITCHED, 4 CMG ACS ADEQUATE FOR<br/>LONG TERM HOLD. <math>30^\circ</math> PITCH CAUSES BIAS<br/>TORQUES THAT SATURATE CMG'S IN A FEW<br/>MINUTES.</p> |
| <p><u>XIOP, ZSL <math>\pm 30^\circ</math> PITCH</u></p>  | <p>4 CMG ACS REQUIRED TO HANDLE<br/>CYCLICAL TORQUES. +1 CMG<br/>FOR BIAS TORQUES + DESATURATION<br/>ONCE/ORBIT</p>                                             |

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# CAPABILITIES FOR EARTH ORIENTED FREE FLYER MISSIONS

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LMSC-D614944-5

## ATTITUDE HOLDING – MINIMUM VEHICLE

XPOP, ZLV  $\pm 90^\circ$  ROLL

SMALL BIAS TORQUE ABOUT X AXIS IF ROLLED. EIGHTY MINUTES TO SATURATION AT  $45^\circ$  ROLL (3CMG ACS)

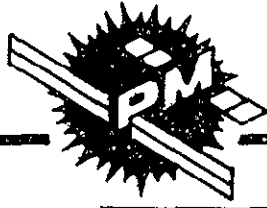
XVV, ZLV  $\pm 90^\circ$  PITCH

NO GRAVITY GRADIENT DISTURBING TORQUES AT  $0^\circ$  PITCH OR  $90^\circ$  PITCH. GRAVITY GRADIENT TORQUES IF PITCHED. 58 MINUTES TO CMG SATURATION AT  $45^\circ$  PITCH (3CMG ACS)

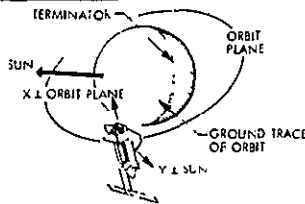
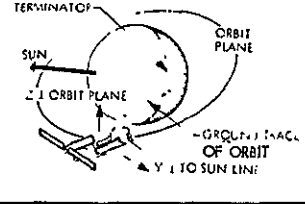
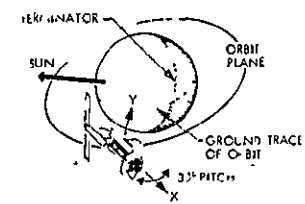
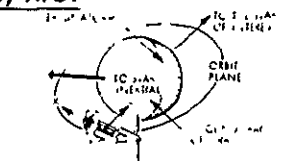
ZLV, YPSL

APPARENT LARGE TORQUES FOR  $\beta < 30^\circ$  DUE TO CROSS COUPLING OF YAW AND ROTATION AT ORBITAL RATE

NO GRAVITY GRADIENT DISTURBING TORQUES



# ATTITUDE HOLDING CAPABILITY INERTIAL FREE FLYER POINTING MODES

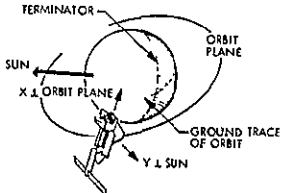
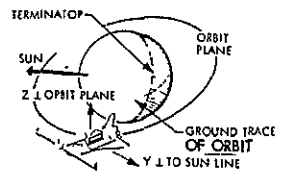
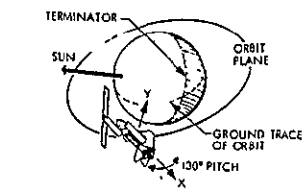
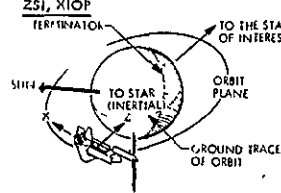
| MODES                                                                                                                                   | CONDITIONS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------------|---------------------------------------|------------------|---|----------|----|----------|----|-----|----|----------|--|----|---|-----|--|----|----|-----|--|----|---|-----|--|----|----|-----|
| <u>XPOP, YPSL</u><br>                                  | 3 CMG ACS ADEQUATE FOR LONG TERM HOLD                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| <u>ZPOP, YPSL</u><br>                                  | 3 CMG ACS ADEQUATE FOR LONG TERM HOLD                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| <u>XIOP, ZSL <math>\pm 30^\circ</math> PITCH</u><br> | <table><tr><th>HOLD TIMES WITH 3 CMG ACS:</th><th><math>\beta</math><br/>DEG</th><th>PITCH<br/>DEG</th><th>TIME<br/>MIN</th></tr><tr><td></td><td>0</td><td>0</td><td><math>\infty</math></td></tr><tr><td></td><td>0</td><td>30</td><td><math>\infty</math></td></tr><tr><td></td><td>30</td><td>0</td><td>187</td></tr><tr><td></td><td>30</td><td>30</td><td>195</td></tr><tr><td></td><td>45</td><td>0</td><td>161</td></tr><tr><td></td><td>45</td><td>30</td><td>150</td></tr></table> | HOLD TIMES WITH 3 CMG ACS: | $\beta$<br>DEG | PITCH<br>DEG                          | TIME<br>MIN      |   | 0        | 0  | $\infty$ |    | 0   | 30 | $\infty$ |  | 30 | 0 | 187 |  | 30 | 30 | 195 |  | 45 | 0 | 161 |  | 45 | 30 | 150 |
| HOLD TIMES WITH 3 CMG ACS:                                                                                                              | $\beta$<br>DEG                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | PITCH<br>DEG               | TIME<br>MIN    |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
|                                                                                                                                         | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 0                          | $\infty$       |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
|                                                                                                                                         | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 30                         | $\infty$       |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
|                                                                                                                                         | 30                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 0                          | 187            |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
|                                                                                                                                         | 30                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 30                         | 195            |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
|                                                                                                                                         | 45                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 0                          | 161            |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
|                                                                                                                                         | 45                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 30                         | 150            |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| <u>ZSI, XIOP</u><br>                                 | <table><tr><th>HOLD TIME (3 CMG ACS)</th><th></th></tr><tr><td>ANGLE BETWEEN<br/>Z AXIS &amp; ORBIT PLANE</td><td>HOLD TIME<br/>MIN</td></tr><tr><td>0</td><td><math>\infty</math></td></tr><tr><td>30</td><td>187</td></tr><tr><td>45</td><td>161</td></tr></table>                                                                                                                                                                                                                         | HOLD TIME (3 CMG ACS)      |                | ANGLE BETWEEN<br>Z AXIS & ORBIT PLANE | HOLD TIME<br>MIN | 0 | $\infty$ | 30 | 187      | 45 | 161 |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| HOLD TIME (3 CMG ACS)                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| ANGLE BETWEEN<br>Z AXIS & ORBIT PLANE                                                                                                   | HOLD TIME<br>MIN                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| 0                                                                                                                                       | $\infty$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| 30                                                                                                                                      | 187                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |
| 45                                                                                                                                      | 161                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                |                                       |                  |   |          |    |          |    |     |    |          |  |    |   |     |  |    |    |     |  |    |   |     |  |    |    |     |

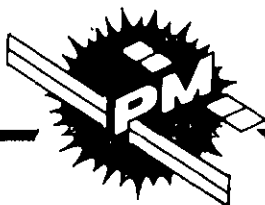
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# HEAT REJECTION CAPABILITY INERTIAL POINTING MODES

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| MODES                                                                                                                                      | CONDITIONS                                                                                                                                          | HEAT REJECTION (1)             |                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|--------------------------------------|
| <p><u>XPOP, YPSL</u></p>                                  | <p>ZSI <math>\beta = 0^\circ</math><br/>MXSI <math>\beta = 70^\circ</math></p>                                                                      | <p>PM<br/>18.7 kW<br/>22.4</p> | <p>PM + ORB<br/>42.5 kW<br/>54.1</p> |
| <p><u>ZPOP, YPSL</u></p>                                  | <p>MXSI, YPOP <math>\beta = 0^\circ</math></p>                                                                                                      | <p>22.4</p>                    | <p>54.1</p>                          |
| <p><u>XPOP, ZSL <math>\pm 30^\circ</math> PITCH</u></p>  | <p>ZSI <math>\beta = 0^\circ</math>, 0 PITCH</p>                                                                                                    | <p>18.7</p>                    | <p>42.5</p>                          |
| <p><u>ZSI, XPOP</u></p>                                 | <p>ZSI, YPOP, <math>\beta = 0^\circ</math><br/>YLV, ZPOP (90° ROLL) <math>\beta = 0^\circ</math><br/>ZSI, ZPOP <math>\beta = 70-90^\circ</math></p> | <p>18.7<br/>20.6<br/>16.3</p>  | <p>42.5<br/>51.6<br/>34.5</p>        |



## CAPABILITIES FOR EARTH ORIENTED SORTIE MISSIONS

### TOTAL HEAT REJECTION (kW)

(XPOP, ZLV  $\pm 90^\circ$  ROLL)

$0^\circ$  ROLL – LOW BETA: 41.5

$0^\circ$  ROLL – HIGH BETA: 39.1

$90^\circ$  ROLL – LOW BETA: 37.5

$90^\circ$  ROLL – HIGH BETA: 34.0

(XVV, ZLV  $\pm 90^\circ$  PITCH)

$0^\circ$  PITCH – LOW BETA: 41.5

$0^\circ$  PITCH – HIGH BETA: 30.9

$90^\circ$  PITCH – LOW BETA: 51.6

$90^\circ$  PITCH – HIGH BETA: 51.6

(ZLV, YPSL)

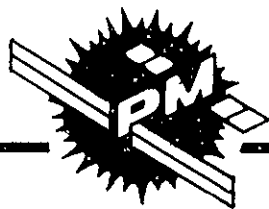
LOW BETA: 41.5

HIGH BETA: 30.9

XLV, ZPOP

LOW BETA: 50.5

HIGH BETA: 47.8



# CAPABILITIES FOR EARTH ORIENTED FREE FLYER MISSIONS

## TOTAL HEAT REJECTION (kW)

|                                                 |                        |      |
|-------------------------------------------------|------------------------|------|
| <u>XPOP, ZLV <math>\pm 90^\circ</math> ROLL</u> | 0° ROLL – LOW BETA:    | 20.6 |
|                                                 | 0° ROLL – HIGH BETA:   | 19.5 |
|                                                 | 90° ROLL – LOW BETA:   | 16.6 |
|                                                 | 90° ROLL – HIGH BETA:  | 15.9 |
| <u>XVV, ZLV <math>\pm 90^\circ</math> PITCH</u> | 0° PITCH – LOW BETA:   | 20.6 |
|                                                 | 0° PITCH – HIGH BETA:  | 15.9 |
|                                                 | 90° PITCH – LOW BETA:  | 20.6 |
|                                                 | 90° PITCH – HIGH BETA: | 20.6 |
| <u>ZLV, YPSL</u>                                | LOW BETA:              | 20.6 |
|                                                 | HIGH BETA:             | 15.9 |
| <u>XLV, ZPOP</u>                                | LOW BETA:              | 16.6 |
|                                                 | HIGH BETA:             | 20.6 |

APPENDIX B  
STO SAMPLE EXPERIMENT

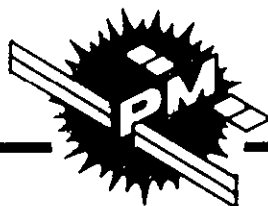
Described herein is a sample experiment planning,  
and evaluation, for an STO mission utilizing the minimum vehicle PM in the sortie mode.

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### STO SAMPLE EXPERIMENT PLANNING

- The chart describes the objective of the sample experiment analysis and sets forth the approach used in carrying it out.





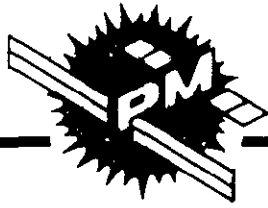
## STO SAMPLE EXPERIMENT PLANNING

---

- OBJECTIVE
- TO DEMONSTRATE INTRODUCTION OF GEOGRAPHICAL FACTORS IN STO ACCOMMODATION ANALYSIS
  - TO EXPLORE ADEQUACY OF AVAILABLE SUN-NADIR VIEWING TIME FOR SCIENTIFIC OBSERVATION
- APPROACH
- DEFINE SAMPLE EXPERIMENT SCIENTIFIC OBJECTIVES
  - DEFINE MEASUREMENT PROGRAM TO ACHIEVE SCIENTIFIC OBJECTIVES
    - INSTRUMENTS
    - VIEWING LOCATIONS
    - OBSERVATION CONDITIONS
  - DEFINE AVAILABILITY OF OBSERVATION OPPORTUNITIES IN SPECIFIED ORBIT
  - ASSESS IMPACT OF SATELLITE CHARACTERISTICS ON EXPERIMENT ACCOMMODATION
    - POINTING CAPABILITIES OF INSTRUMENTS
    - ATTITUDE MODES

## STO SAMPLE EXPERIMENT OBJECTIVES

- Solar activity influences terrestrial phenomena by:
  - Transport of plasma through interplanetary magnetic field and earth's magnetosphere – effect from 1 to 3 days after solar event
  - Direct or scattered radiation, such as X-rays, UV – effect immediate with observation.
- Location of ERA, SAR, and LLA follows magnetic coordinates SAR and LLA influenced mainly by solar plasma; ERA is caused by a recombination process in the F-layer.
- TG and DG mainly result from interaction of solar radiation with the atmosphere, and the ensuing atmospheric chemistry.
- NG is due mainly to delayed effects of solar radiation with some low energy particle precipitation involved.



## STO SAMPLE EXPERIMENT OBJECTIVES

---

TO DETERMINE INFLUENCE OF RECENT SOLAR ACTIVITY ON:

- EQUATORIAL RED ARCS (ERA)
- MID LATITUDE RED ARCS (SAR)
- LOW(ER) LATITUDE AURORAS (LLA)
- TWILIGHT GLOW (TG)
- NIGHT GLOW (NG)
- DAY GLOW (DG)

# STO SAMPLE EXPERIMENT OBSERVATION REQUIREMENTS

- Equat. Red Arc
  - occurs regularly  $\pm 20^{\circ}$  magnetic latitude
  - irregular islands of increased intensity
  - can be seen against dark earth and lower atmosphere
- Stable Arc, Red
  - generally occurs when  $K_p \geq 5 \sim 8\%$  of time
  - lasts for several hours to a few days
  - extend around earth in north and south bands from  $40$  to  $60^{\circ}$  magnetic latitude
  - bright arcs can be seen against darkened earth and darkened atmosphere below about 50 km
- Lower Lat. Aurora
  - occurs after increased solar activity
  - move toward the equator  $10^{\circ}$  from auroral oval perhaps 25 nights/yr
- Twilight Glow
  - for correlation with very recent solar phenomena, will use only terminator crossing from sunlight to darkness
- Observation requirements defined to cover regions for phenomenology occurrence with allowance for variations. Near vertical viewing desired to permit most clear-cut separation of temporal and spatial variations. Simultaneous solar viewing, within reaction time constants, desired for glow and equatorial red arc observation



# STO SAMPLE EXPERIMENT OBSERVATION REQUIREMENTS

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## INSTRUMENTS

- SOLAR POINTING PACKAGE
  - LOW LIGHT LEVEL TV
  - FABRY-PEROT INTERFEROMETER
- } NADIR POINTING

## PRIMARY OBSERVATIONS/CONDITIONS

|                  |                                               |                                               |                            |
|------------------|-----------------------------------------------|-----------------------------------------------|----------------------------|
| EQUAT RED ARC    | $<  30^\circ  \text{LAT.}$                    | $\text{SZA}^* \geq 105^\circ$                 | SIMULTANEOUS SOLAR VIEWING |
| STABLE ARC, RED  | $ 40^\circ \text{ TO } 57^\circ  \text{LAT.}$ | $\text{SZA} \geq 97^\circ$                    |                            |
| LOWER LAT AURORA | $ 30^\circ \text{ TO } 57^\circ  \text{LAT.}$ | $\text{SZA} \geq 97^\circ$                    |                            |
| TWILIGHT GLOW    | $<  57^\circ  \text{LAT.}$                    | $\text{SZA} = 95^\circ \text{ TO } 105^\circ$ | SIMULTANEOUS SOLAR VIEWING |
| NIGHT GLOW       | $<  57^\circ  \text{LAT.}$                    | $\text{SZA} \geq 105^\circ$                   | SIMULTANEOUS SOLAR VIEWING |

## SECONDARY OBSERVATIONS/CONDITIONS

|          |                            |                            |
|----------|----------------------------|----------------------------|
| DAY GLOW | $<  57^\circ  \text{LAT.}$ | $\text{SZA} \leq 90^\circ$ |
|----------|----------------------------|----------------------------|

\* SOLAR ZENITH ANGLE

# STO SAMPLE EXPERIMENT OPPORTUNITIES (I)

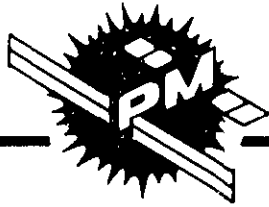
- Conditions

- For terminator crossings, sunlight to darkness
- For simultaneous viewing sun and nadir where SZA  $105^{\circ}$
- For ERA, NG, and TG (high altitude)
- Launch into  $57^{\circ}$  Inc. orbit at 12:00 UT, 21 January\*
- Only one orbit/day is plotted

- Opportunities

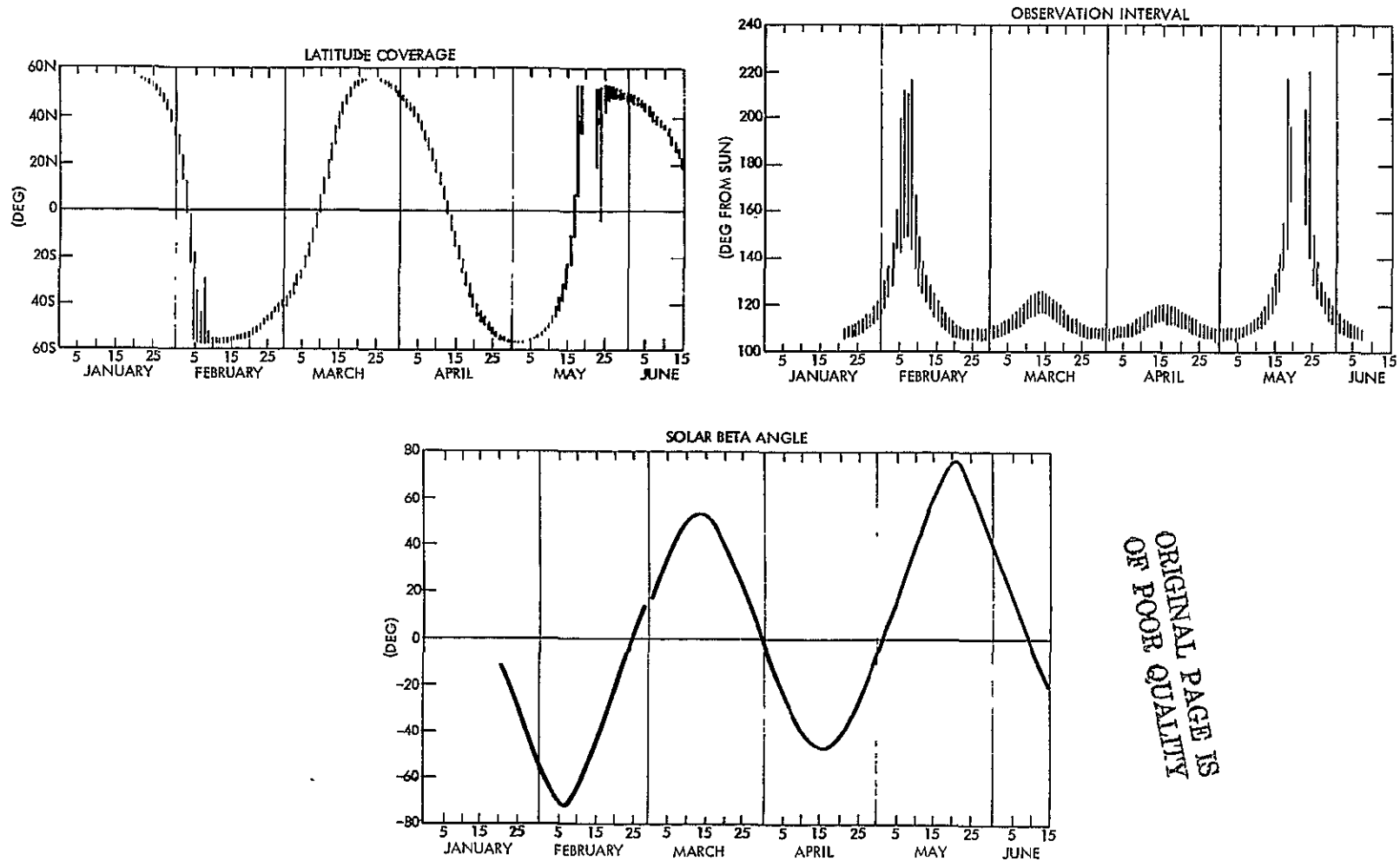
- Latitudinal coverage shown in upper left chart for 5 month period
- Observation Interval ( $20^{\circ}$  = 5 minutes of time) shown at upper right
- Changes in time of day or date of launch will shift these curves very little, once inclination of orbit is fixed.\*
- Solar declination and orbital inclination influence solar beta angle cycles which in turn control short period cycles in latitude coverage and observation interval curves. As a result, adjacent short period cycles differ from each other and the cycles are asymmetric.

\*Once PM is launched, it controls sortie orbits for its useful life.



# STO SAMPLE EXPERIMENT OPPORTUNITIES (I)

OBSERVATION OPPORTUNITIES -- 57° ORBIT  
(NIGHT GLOW; TWILIGHT GLOW; EQUATORIAL RED ARCS)



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## STO SAMPLE EXPERIMENT OPPORTUNITIES (II)

- Conditions
  - Observations of SAR\* and LLA\* to be made when  $\text{SZA} \geq 105^\circ$
  - Need solar monitoring  $\geq 50\%$  of time for preceding 3 days
  - Launch into  $57^\circ$  Inc. Orbit at 12:00 UT, 21 January, assumed
  - For SAR and LLA with solar history (Ordinarily, history when PM is eclipsed by earth can be supplied from ground based and other satellite solar observatories.)
- Opportunities
  - Essentially full night time coverage ( $-57^\circ$  to  $+57^\circ$  latitude) for 15 day periods every 1.5 months.
  - Essentially half-time viewing except when Solar Beta Angle  $\geq 65^\circ$  which for the  $57^\circ$  orbit occurs about 2 days every 3 months

\*SAR and LLA do not occur regularly, so that an on-board monitor is needed to shift to proper operational mode.



## EFFECT OF SATELLITE CHARACTERISTICS ON STO SAMPLE EXPERIMENT

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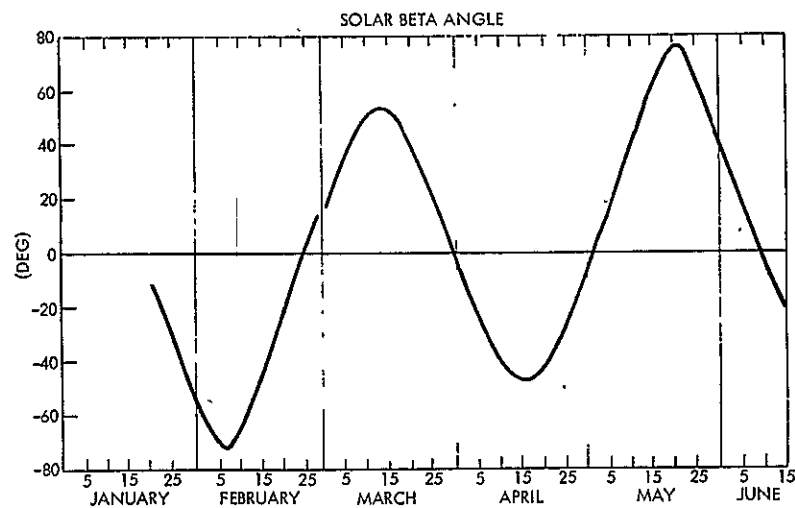
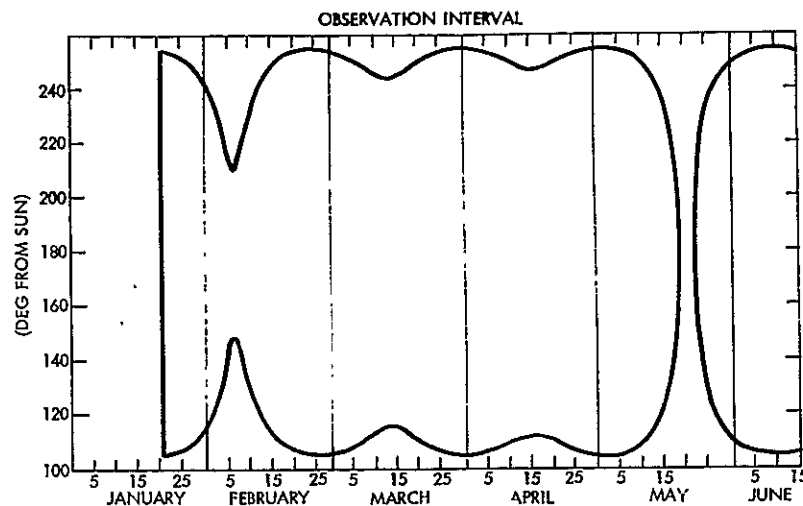
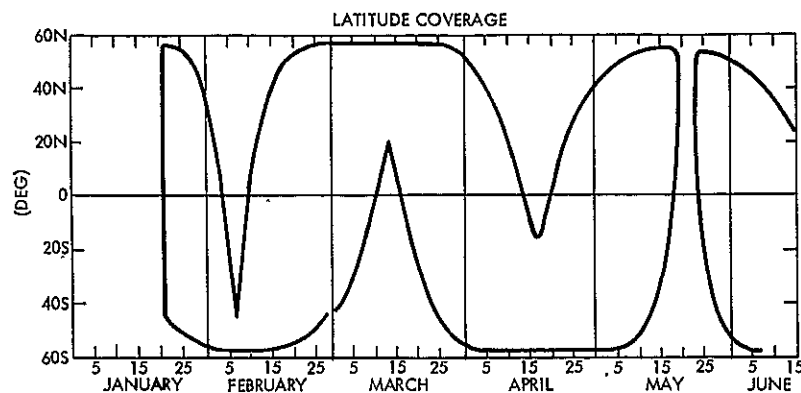
- Portions of orbits are shown where simultaneous sun-nadir observations at sunlight to dark terminator crossings are possible for low, medium and high beta angles (for TG and ERA measurements). (OBS-1)
- Also shown are portions of orbits where nadir measurements against dark earth ( $SZA \geq 105^\circ$ ) are possible for low, medium and high beta angles (for NG, SAR, and LLA measurements) )solar history adequate, simultaneous viewing not required). (OBS-2)
- Attitude XPOP, YPSL    —    for mid  $\beta$ ,  $\sim 2$  min OBS-1/orbit  
                                      for high  $\beta$ ,  $\sim 25$  min OBS-1/orbit  
                                      for all  $\beta$ ,  $\geq 30$  min OBS-2/orbit  
                                      deficient for DG measurements, provides full power at all  $\beta$ .
- Attitude XPOP, ZLV    —    for mid  $\beta$ ,  $\sim 2$  min OBS-1/orbit  
                                      for high  $\beta$ ,  $\sim 25$  min OBS-1/orbit  
                                      for  $\beta \geq 40^\circ$ ,  $\geq 30$  min OBS-2/orbit  
                                      for high  $\beta$ , simultaneous sun-nadir DG measurements (secondary requirement)  
                                      gives full power.
- Attitude XVV, ZLV    —    for all  $\beta$ , same as XPOP, YPSL on primary measurements  
                                      for low  $\beta$ , 50% secondary, (DG) measurement, full power
- Conclusions:            —    some simultaneous viewing of sun-nadir is possible in all altitudes considered,  
                                      with ability to obtain meaningful data.

STO 33-T



## STO SAMPLE EXPERIMENT OPPORTUNITIES (II)

OBSERVATION OPPORTUNITIES – 57° ORBIT  
(STABLE ARCS, RED; LOWER LATITUDE AURORAS)

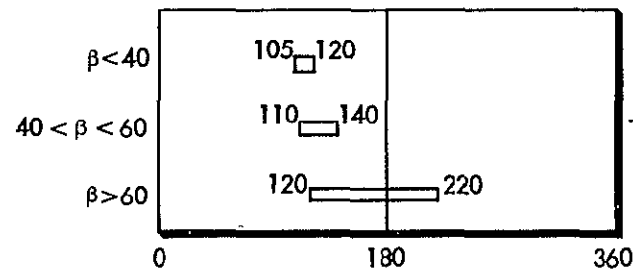


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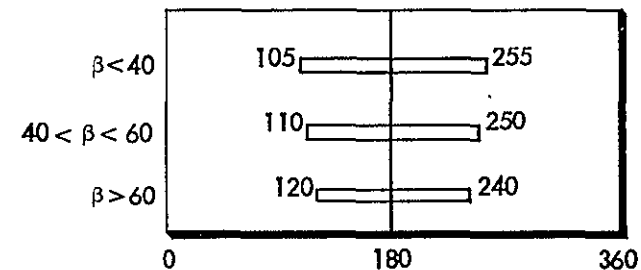


# EFFECT OF SATELLITE CHARACTERISTICS ON STO SAMPLE EXPERIMENT

TWILIGHT GLOW, ERA MEASUREMENTS

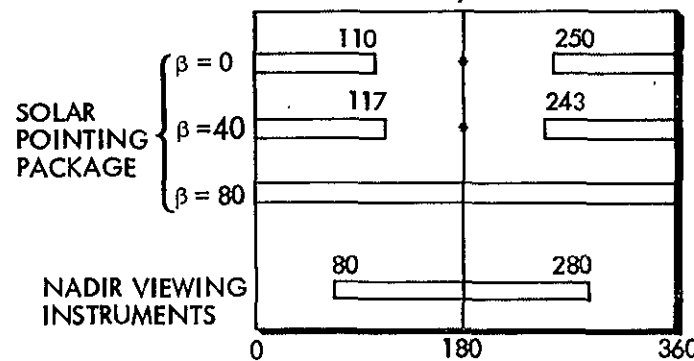


NIGHT GLOW MEASUREMENTS

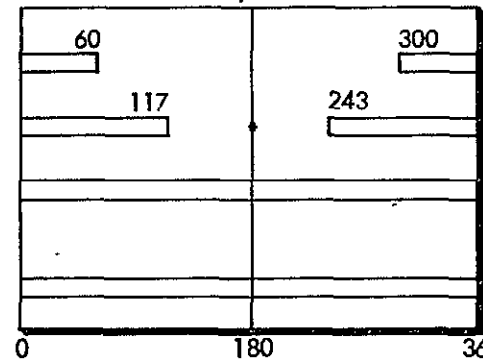


ORBITAL ANGLE FROM SUN FOR EXPERIMENTAL CONDITIONS

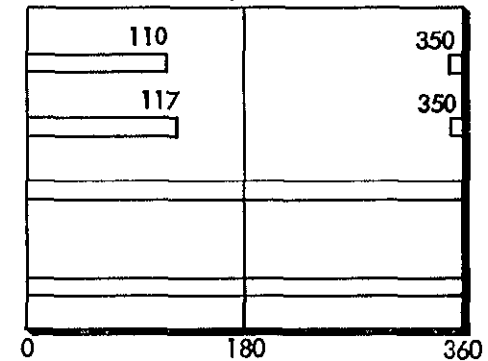
XPOP, YPSL



XPOP, ZLV



XVV, ZLV



ORBITAL ANGLE FROM SUN FOR PRIMARY VIEWING

\*OCCULTATION LIMITS

## APPENDIX C

### INTRODUCTION

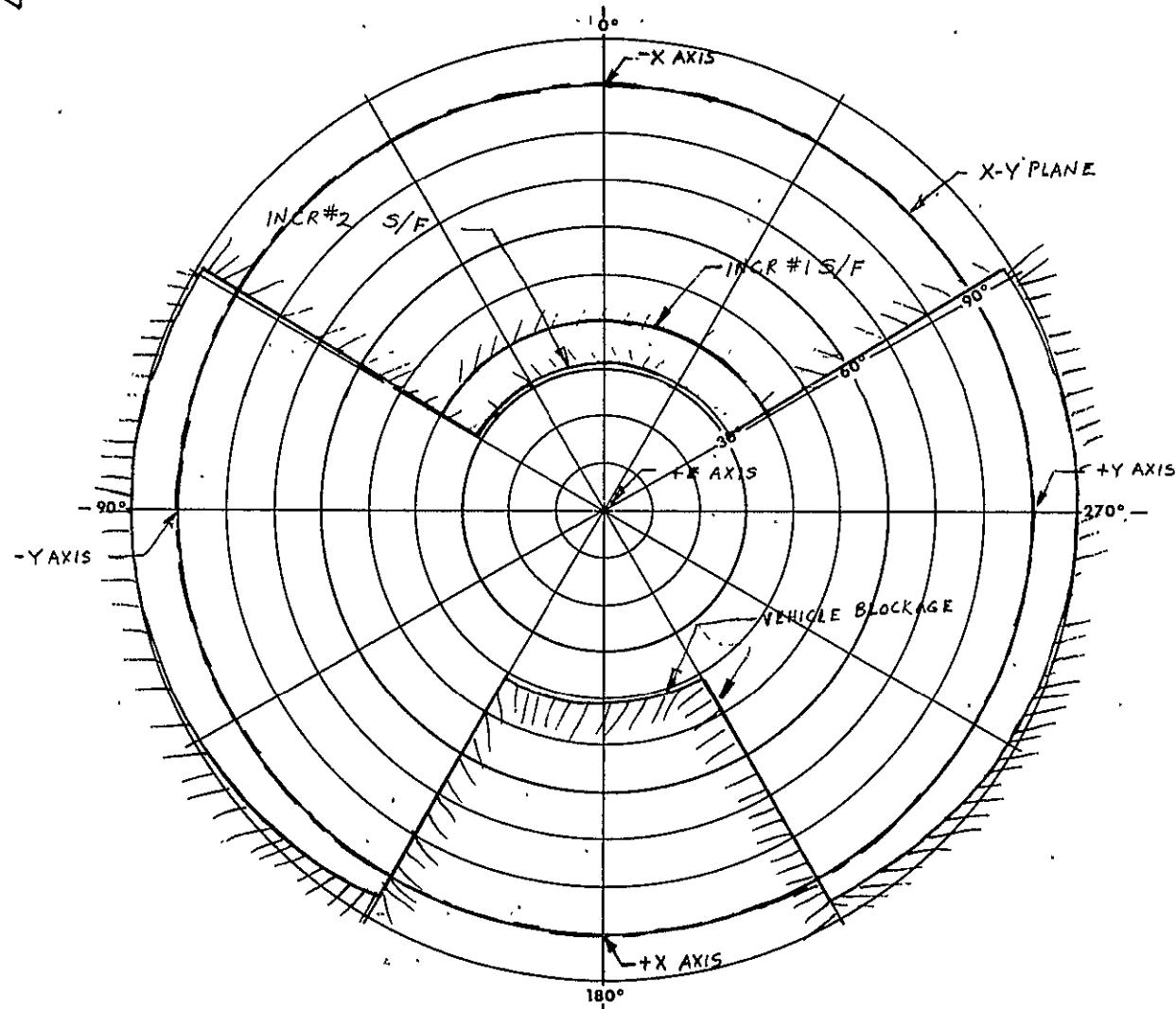
- These charts represent a compendium of STO viewing capability angles, viewing conditions, and mission viewing capabilities within an orbit.
- The first seven charts, entitled "Viewing Capability Angle," define the viewing capability angle limits of payload pallets in both sortie and free-flyer modes. In this analysis the orbiter and free-flyer pallets are attached to the PM.
- The next five charts, entitled "Viewing Conditions," define target directions relative to PM/orbiter/attitudes for a variety of vehicles.
- The next six charts, entitled "STO Mission Viewing Capabilities", show the payload target viewing coverage possible within an orbit for each vehicle attitude mode used.
- As an aid in the use of the above charts the next chart, entitled "STO Viewing Composite INCR No. 1 and 2", is an example of the viewing condition chart overlaid by the viewing capability angle chart and resulting in target visibility in degrees. The points of interest are marked by the numbers in triangular symbols.
- The last chart, entitled "STO Viewing Composite Summary," indicates the points referenced on the previous chart and the associated data. The triangles with the same numbers are also shown on "STO Mission Viewing Capabilities XIOP, ZSL" in final form.

REPRODUCTION OF THIS PAGE IS PROHIBITED



# VIEWING CAPABILITY ANGLE

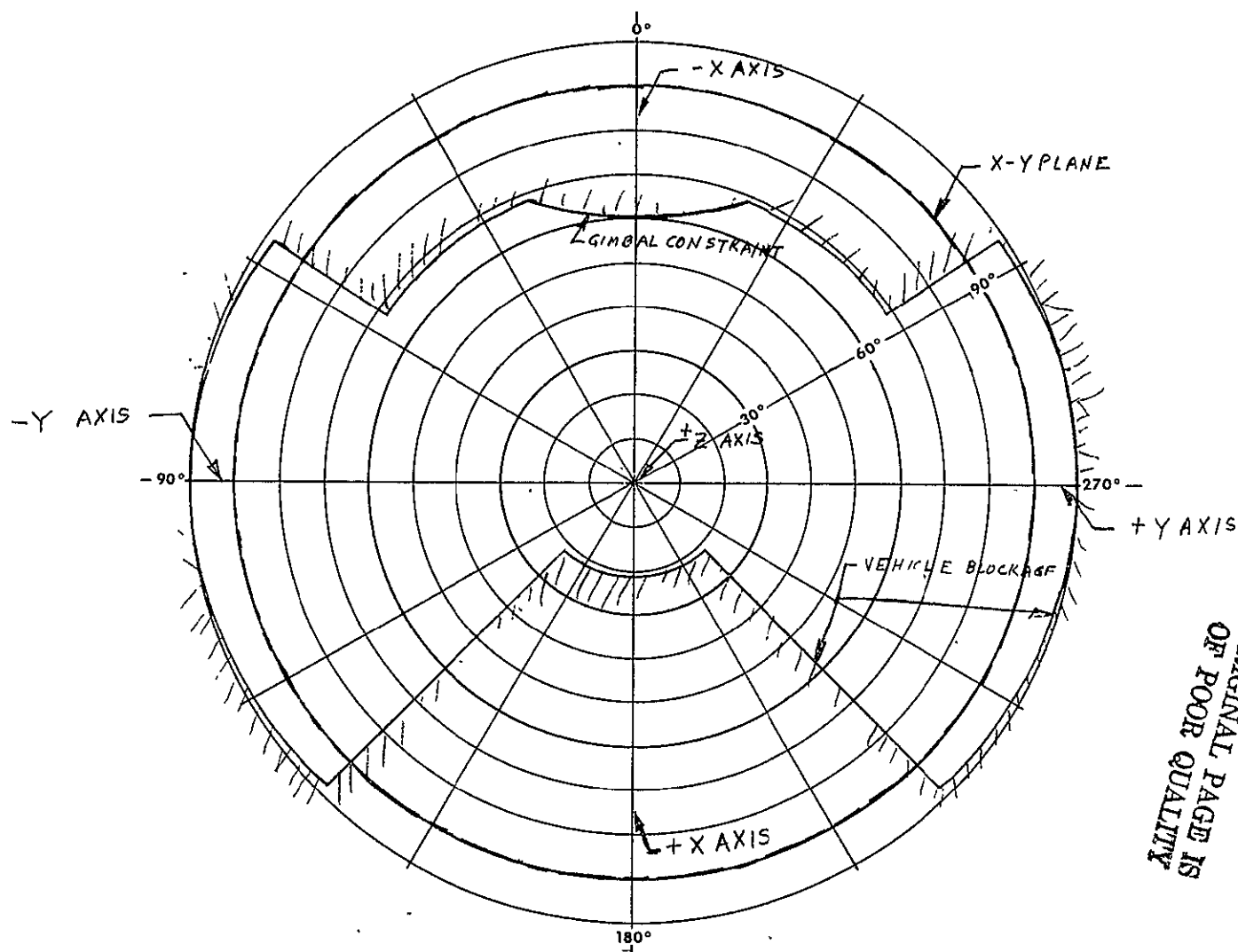
STO INCR NO. 1 & 2 SORTIE FORWARD PALLET





# VIEWING CAPABILITY ANGLE

STO INCR NO. 1 SORTIE AFT

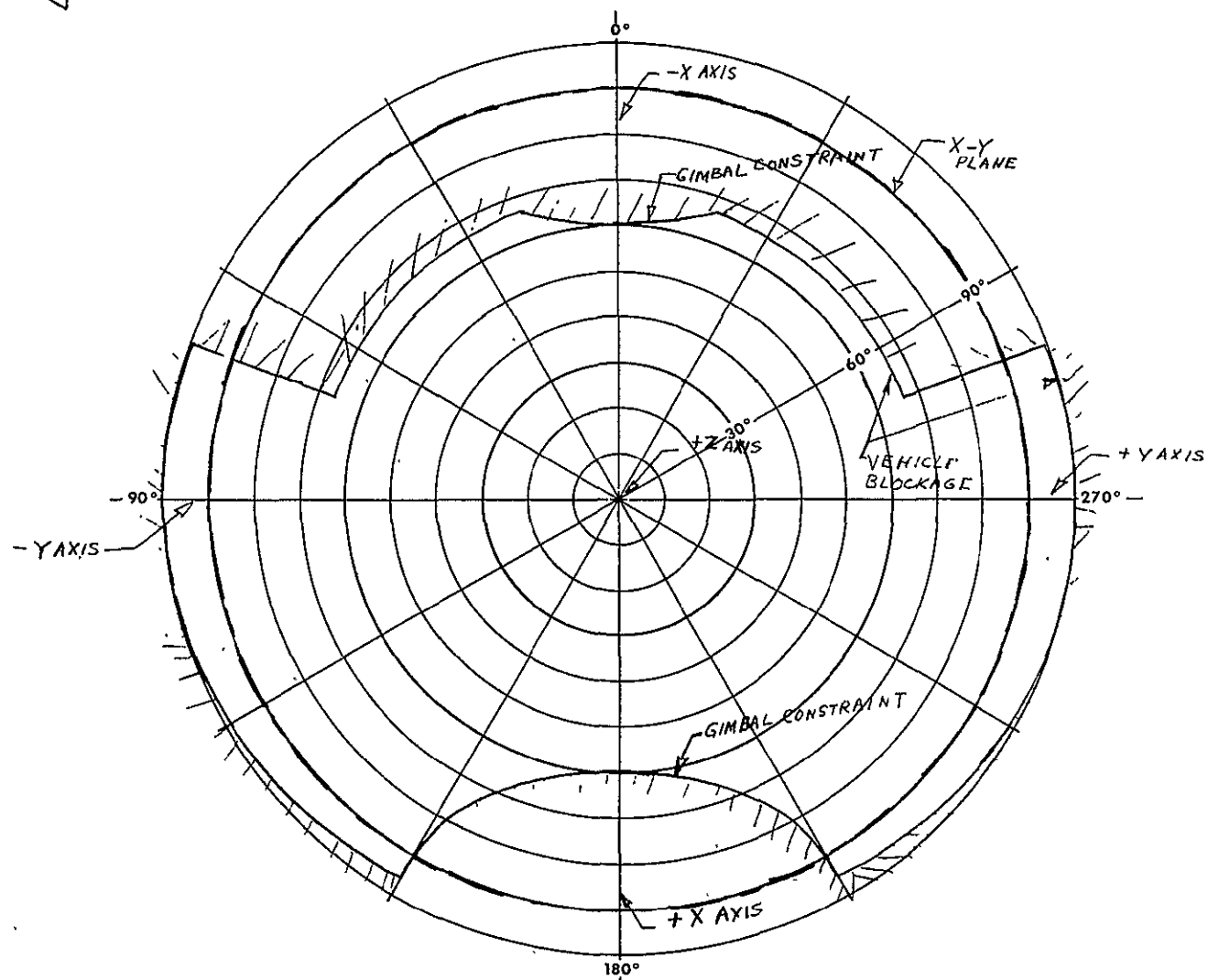


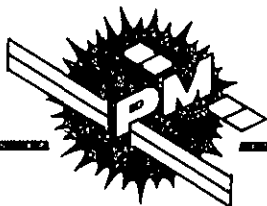
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# VIEWING CAPABILITY ANGLE

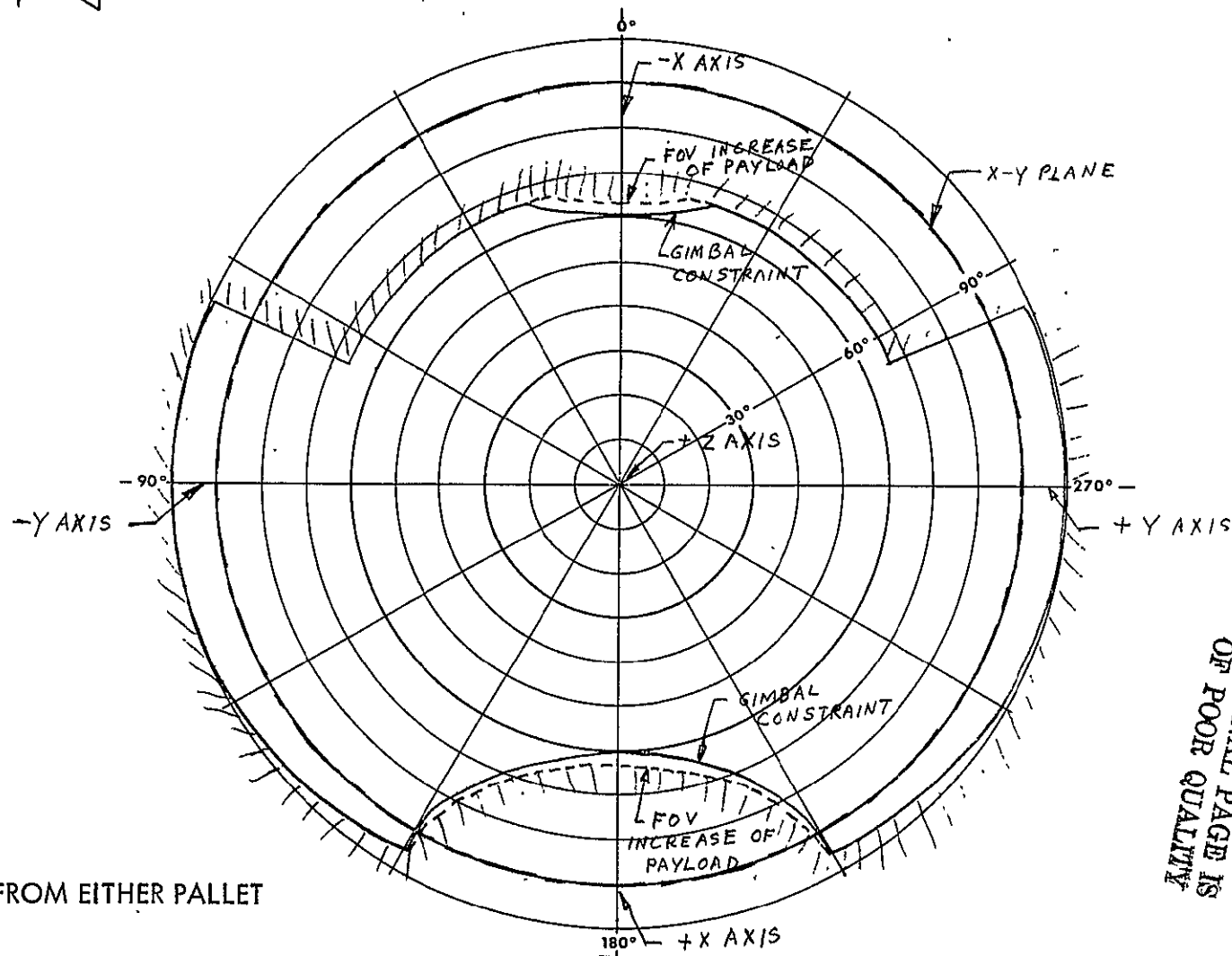
STO INCR NO. 1 & 2 FFP FWD





# VIEWING CAPABILITY ANGLE

STO INCR NO. 2 FFP FWD U 2A \*



\*VIEWING FROM EITHER PALLET

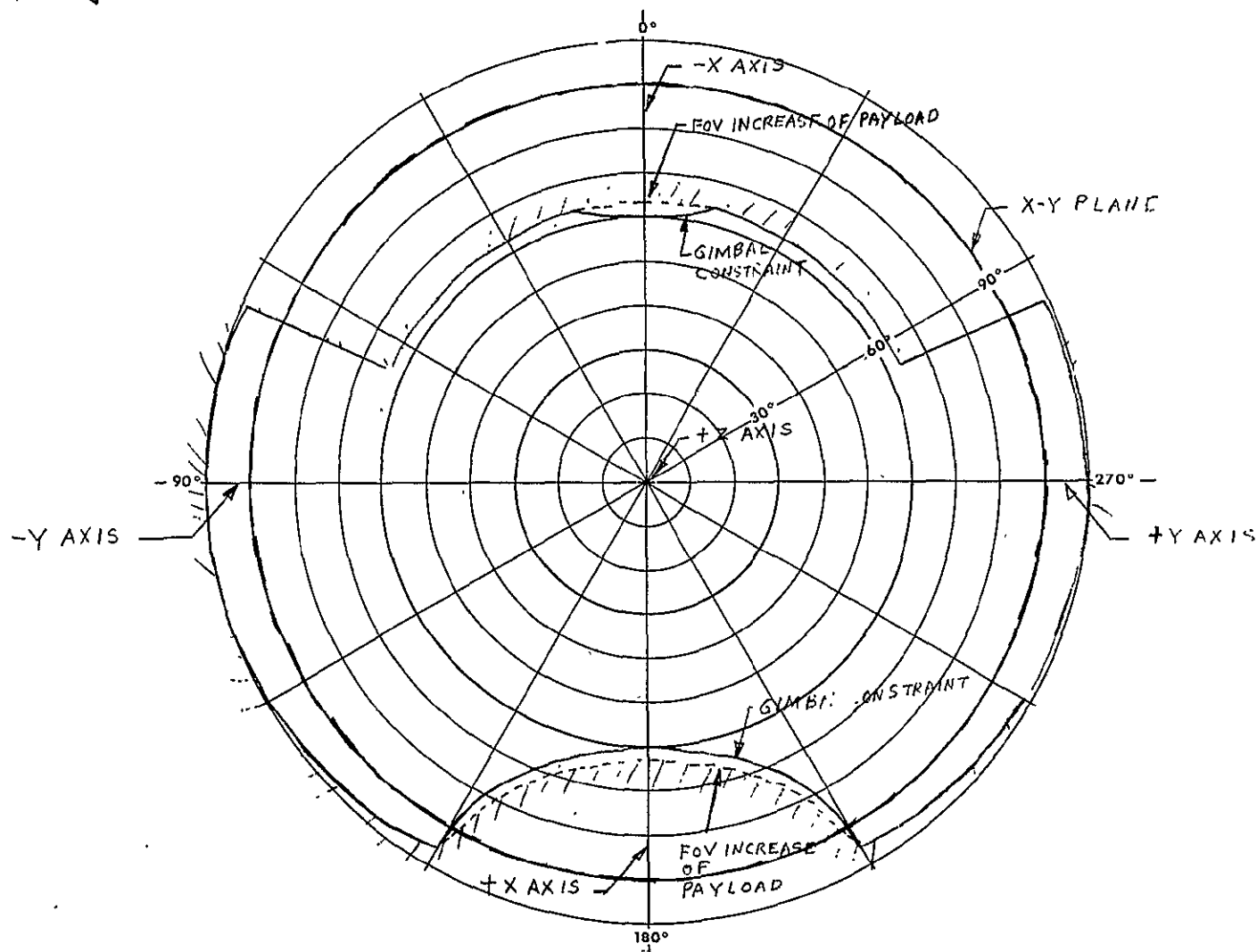
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# VIEWING CAPABILITY ANGLE

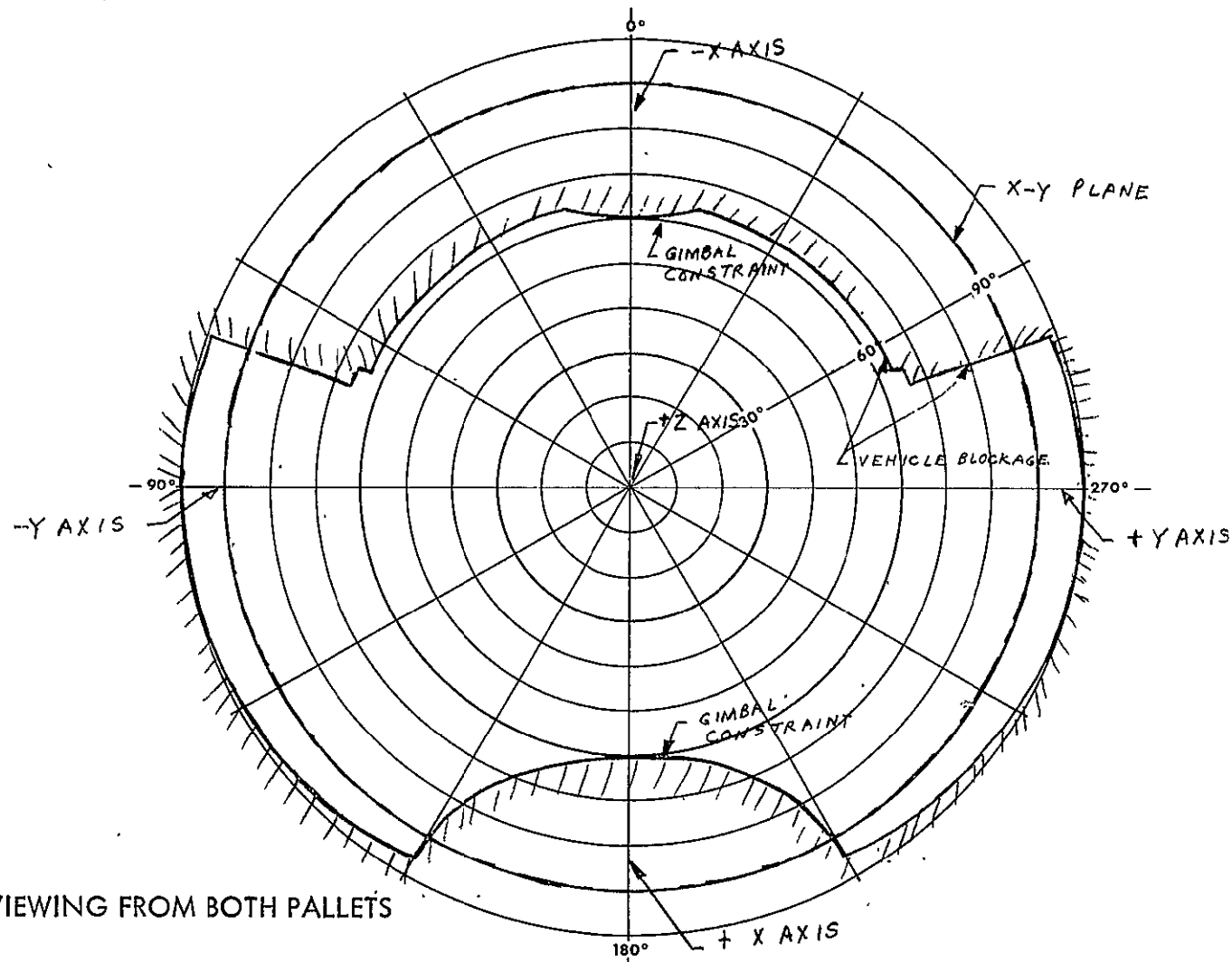
STO INCR NO. 2 FFP 2A





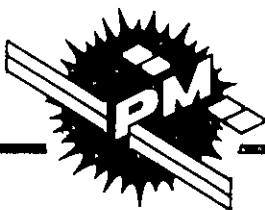
# IEWING CAPABILITY ANGLE

STO INCR NO. 2 FFP FWD 2A \*



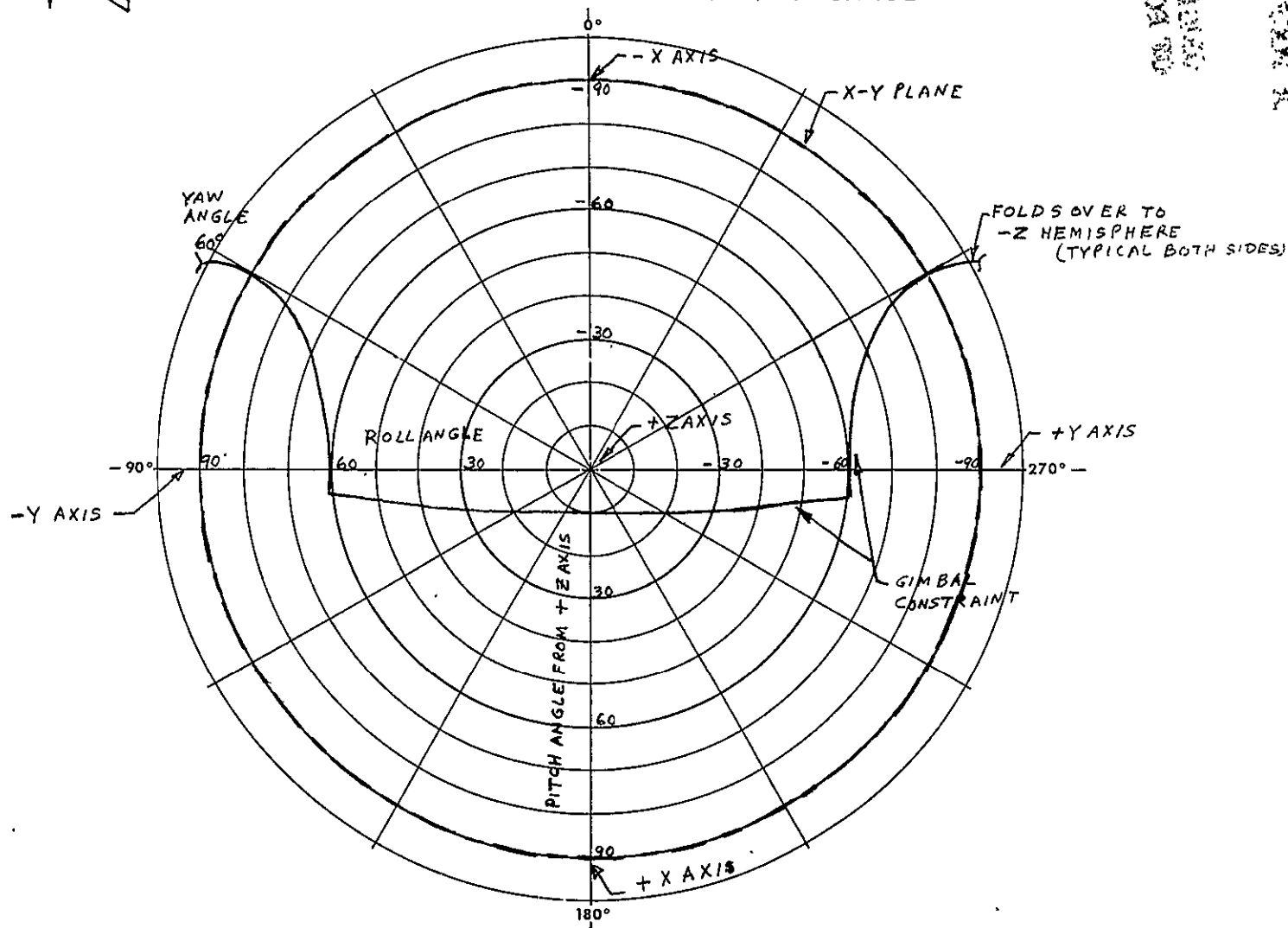
\*SIMULTANEOUS VIEWING FROM BOTH PALLETS

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# VIEWING CAPABILITY

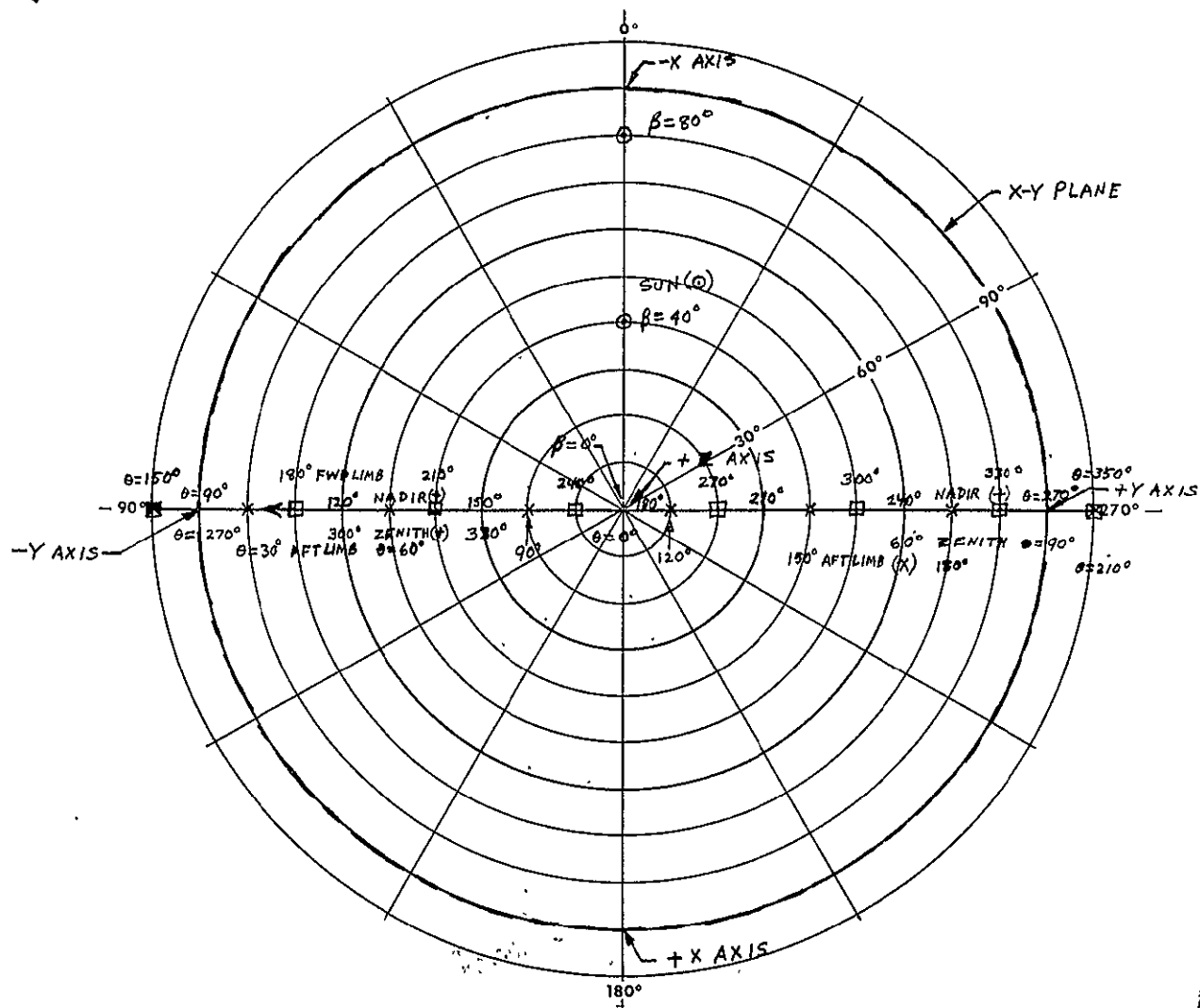
STO INCR NO. 1 & 2 SOLAR POINTING PACKAGE



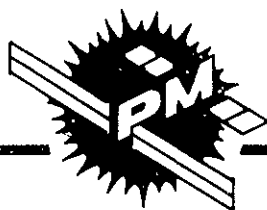


# VIEWING CONDITIONS

(M) X POP, YPSL ATTITUDE

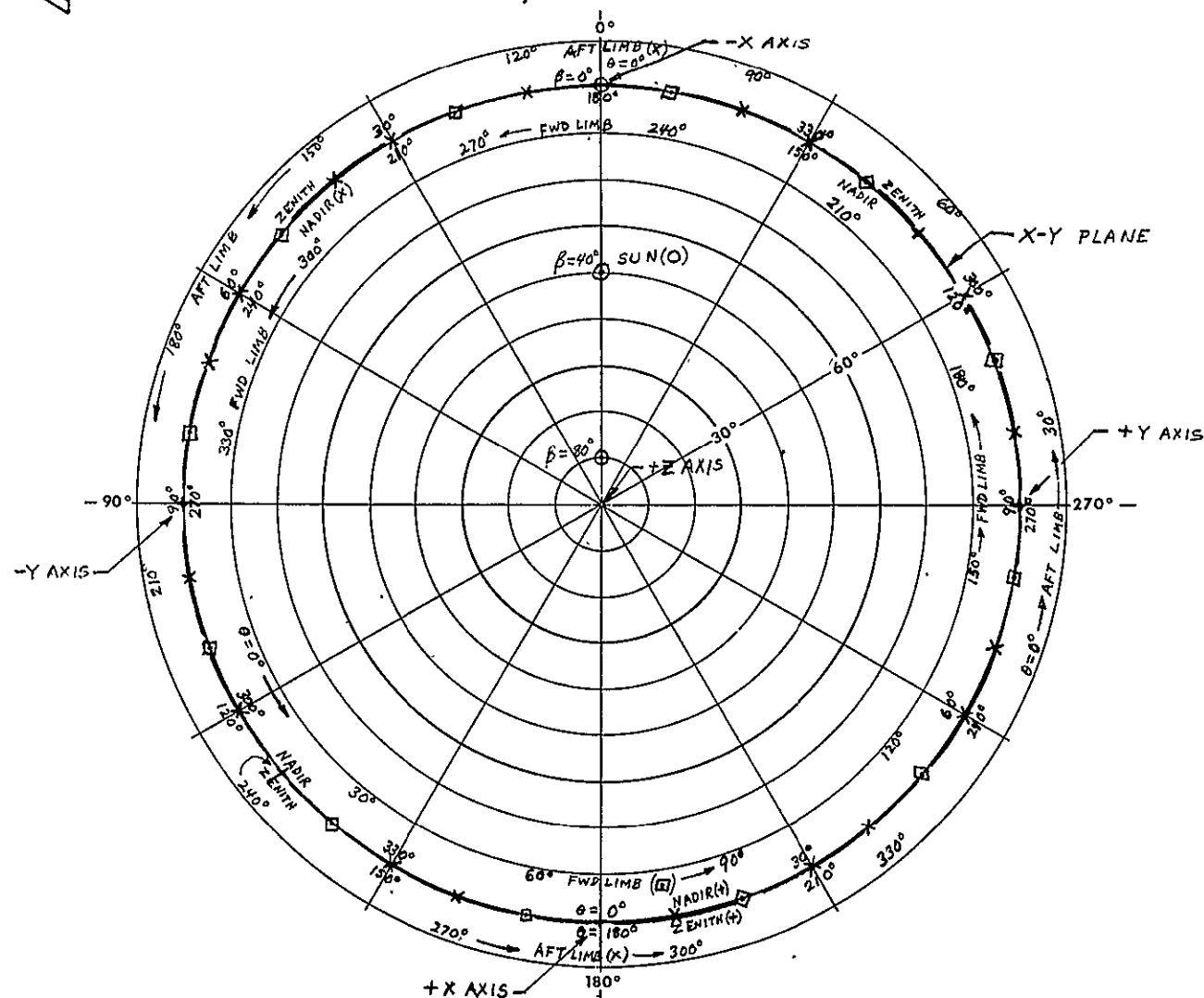


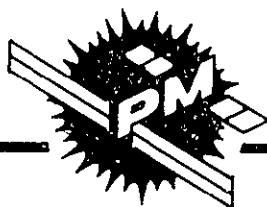
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# VIEWING CONDITIONS

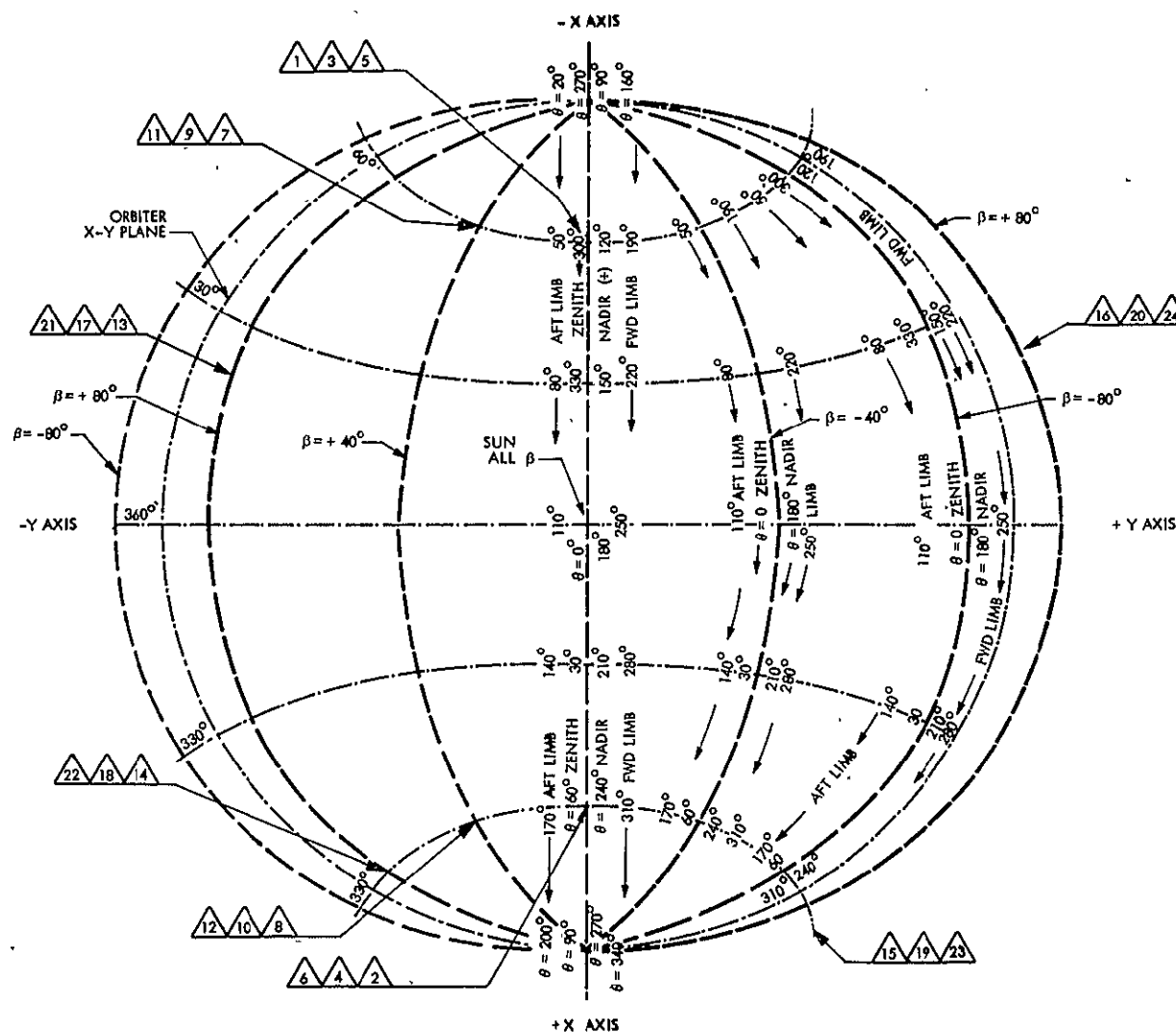
Z POP, YPSL ATTITUDE





# VIEWING CONDITIONS

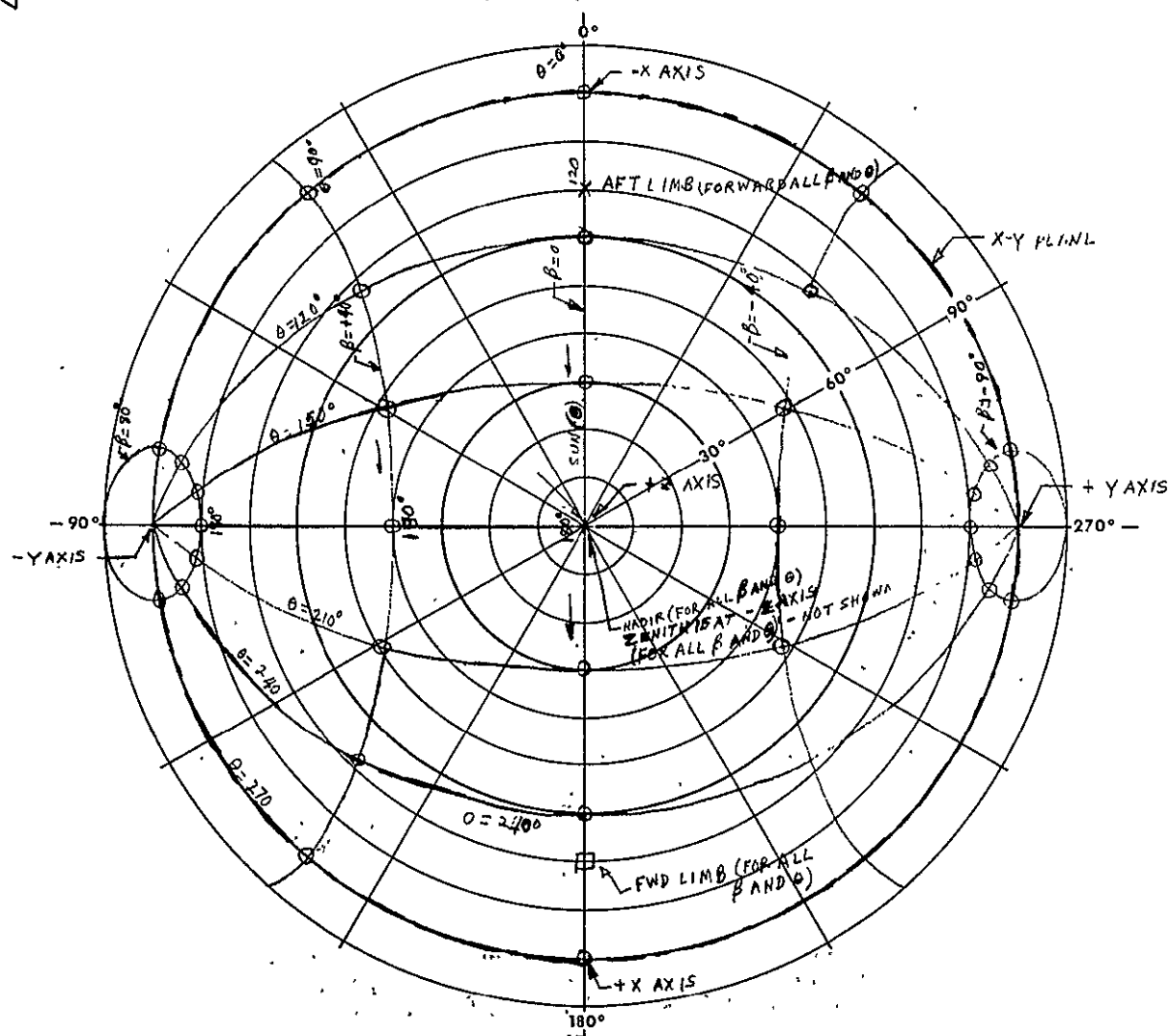
XIOP, ZSL





# VIEWING CONDITIONS

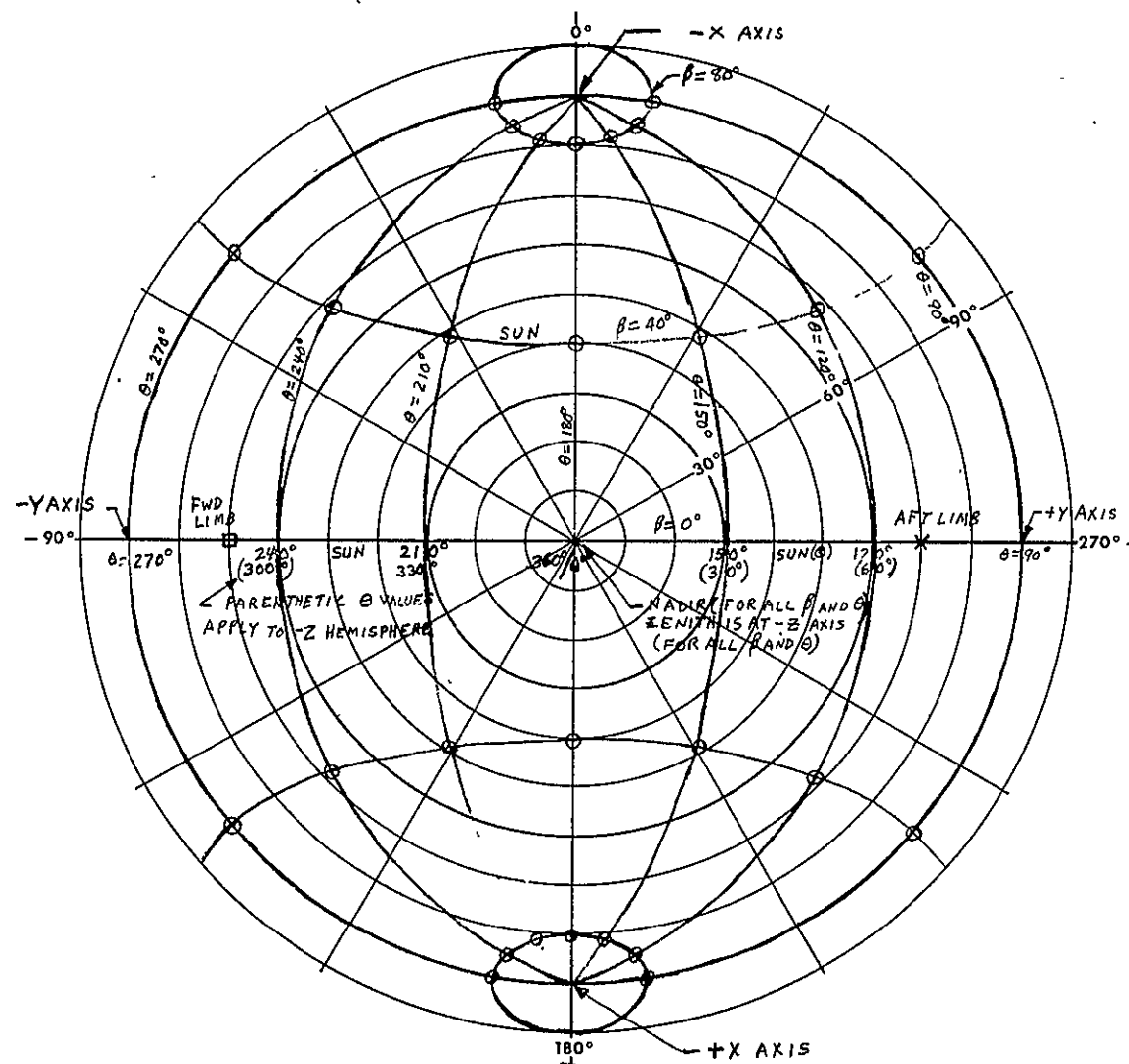
XVV, ZLV ATTITUDE





# VIEWING CONDITIONS

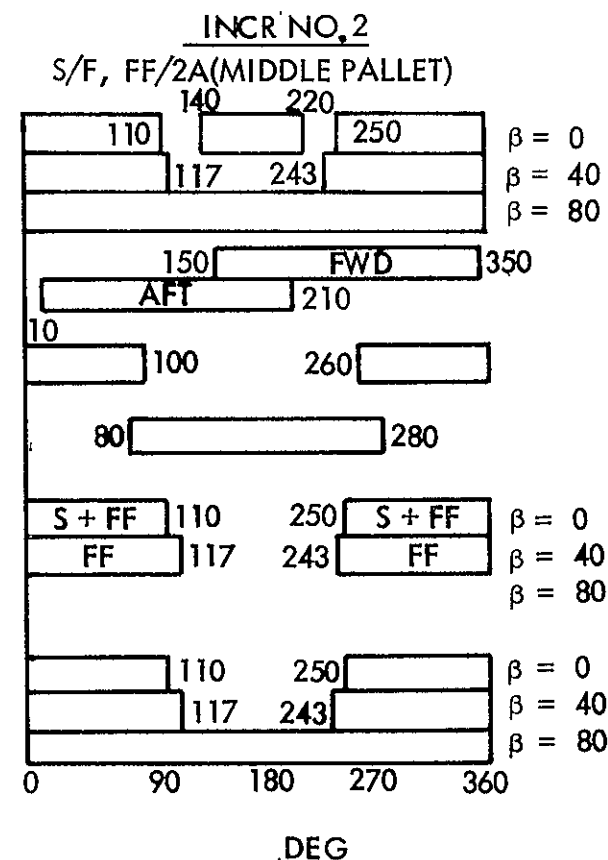
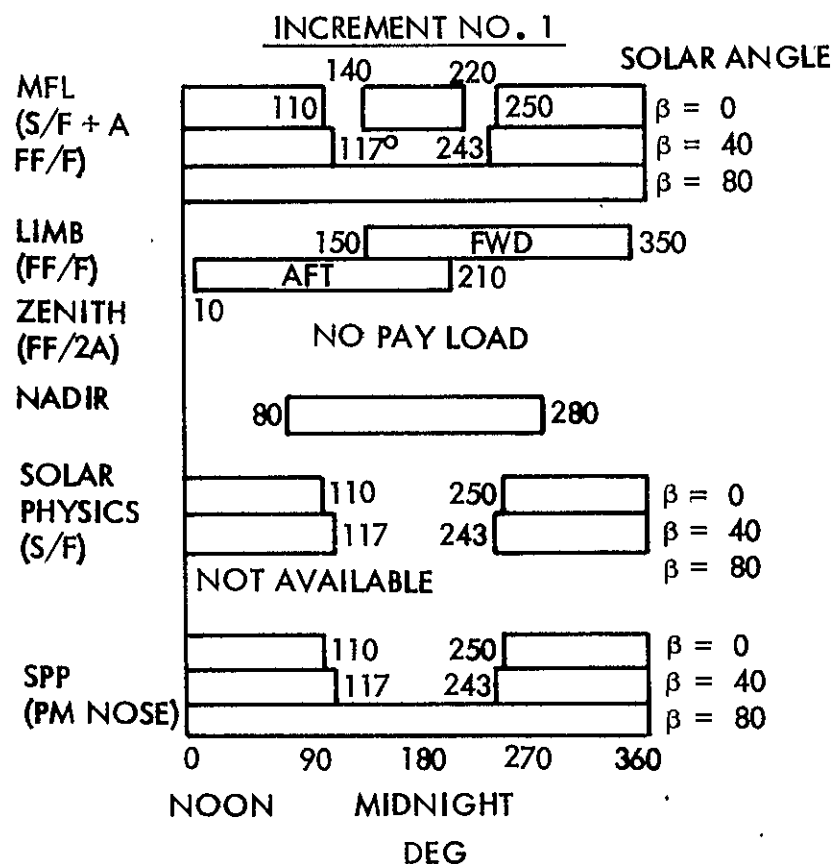
(M) X POP, ZLV ATTITUDE







# STO MISSION VIEWING CAPABILITIES (M)×POP, YPSL, ATTITUDE

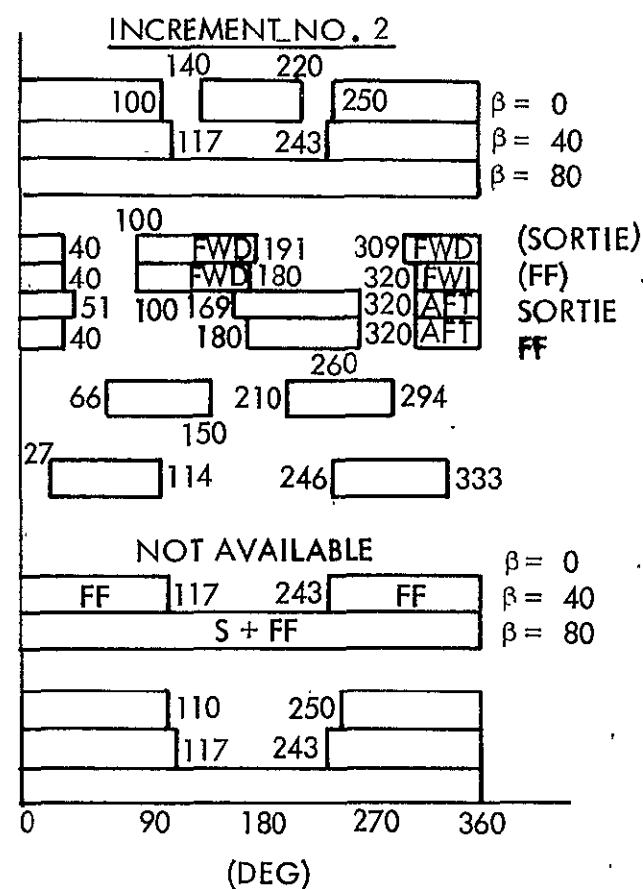
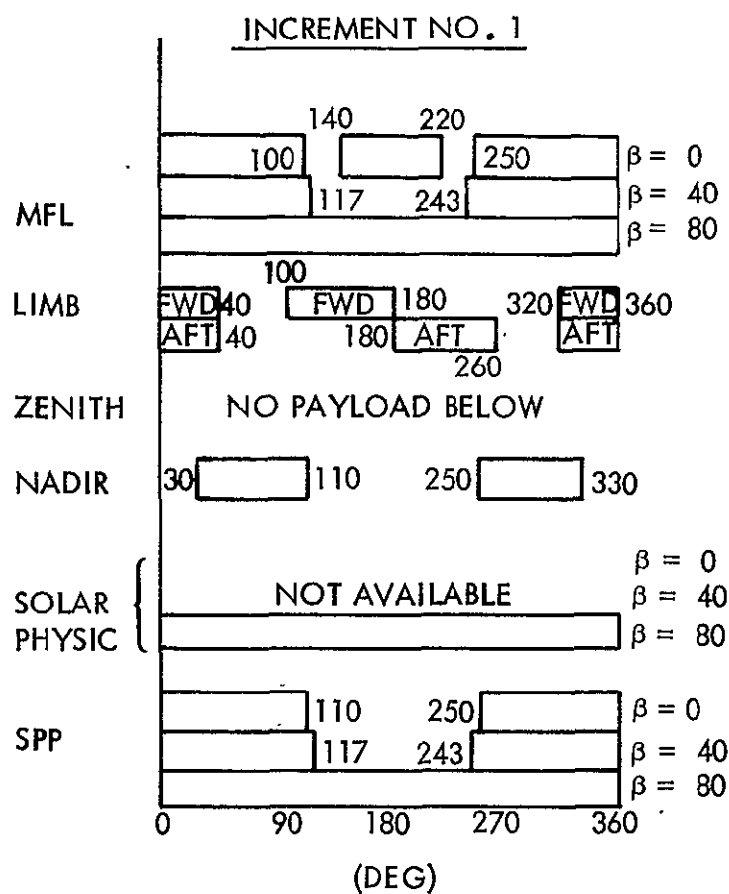


MFL – MAGNETIC FIELD LINES  
SPP – SOLAR POINTING PACKAGE  
S/F – SORTIE FORWARD  
+A – AFT



# STO MISSION VIEWING CAPABILITIES

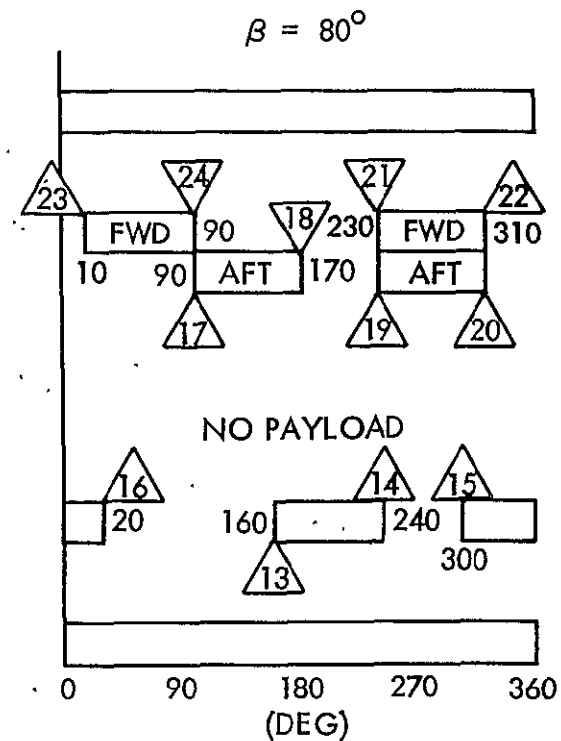
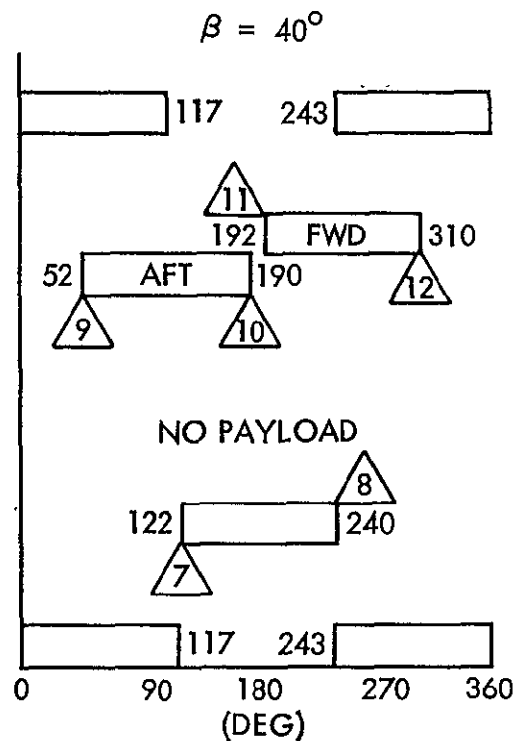
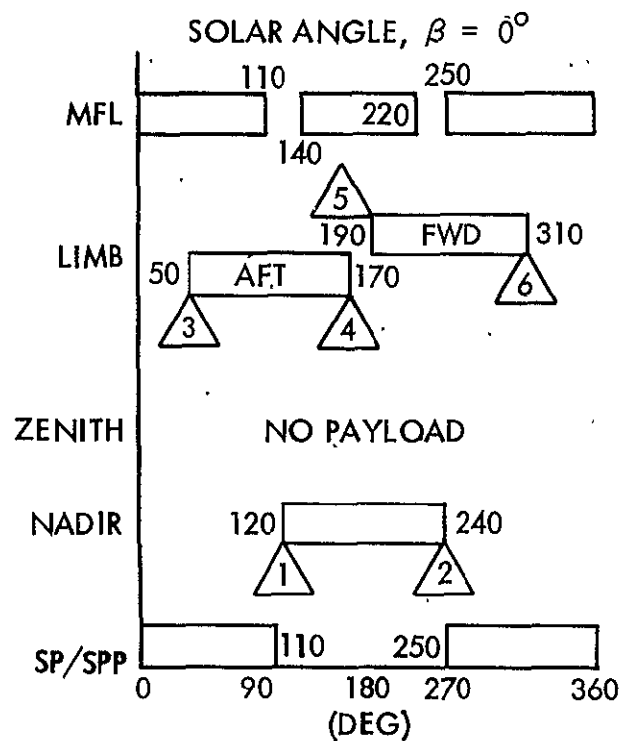
- X AXIS TOWARD THE SUN





# STO MISSION VIEWING CAPABILITIES XIOP, ZSL, ATTITUDE

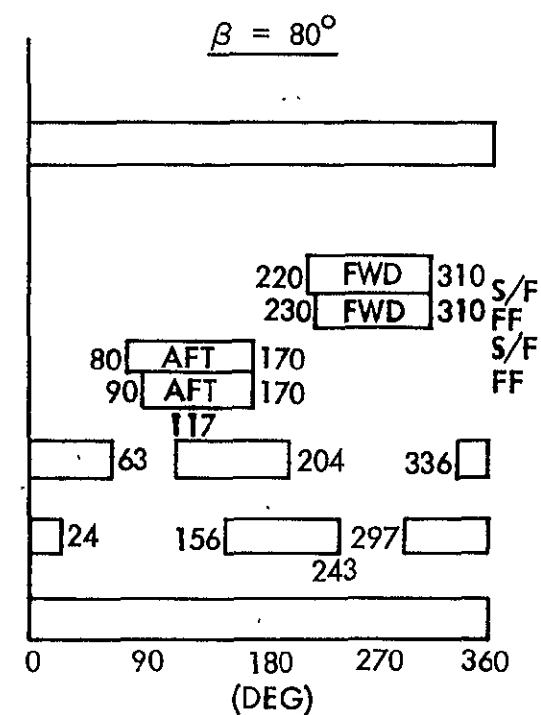
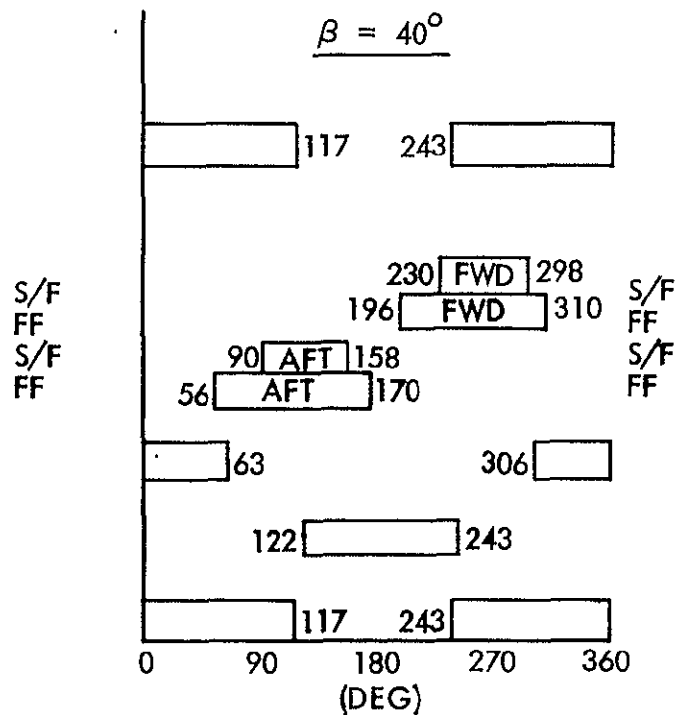
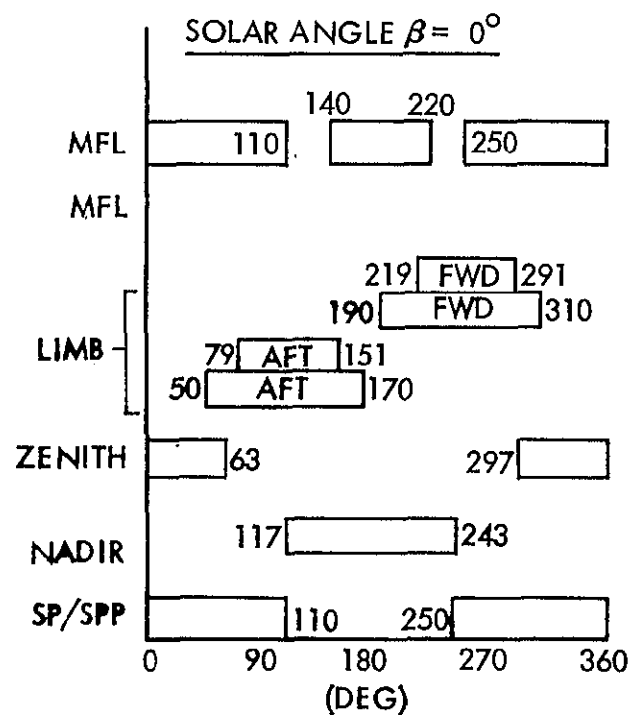
INCREMENT NO. 1





# STO MISSION VIEWING CAPABILITIES XIOP, ZSL, ATTITUDE

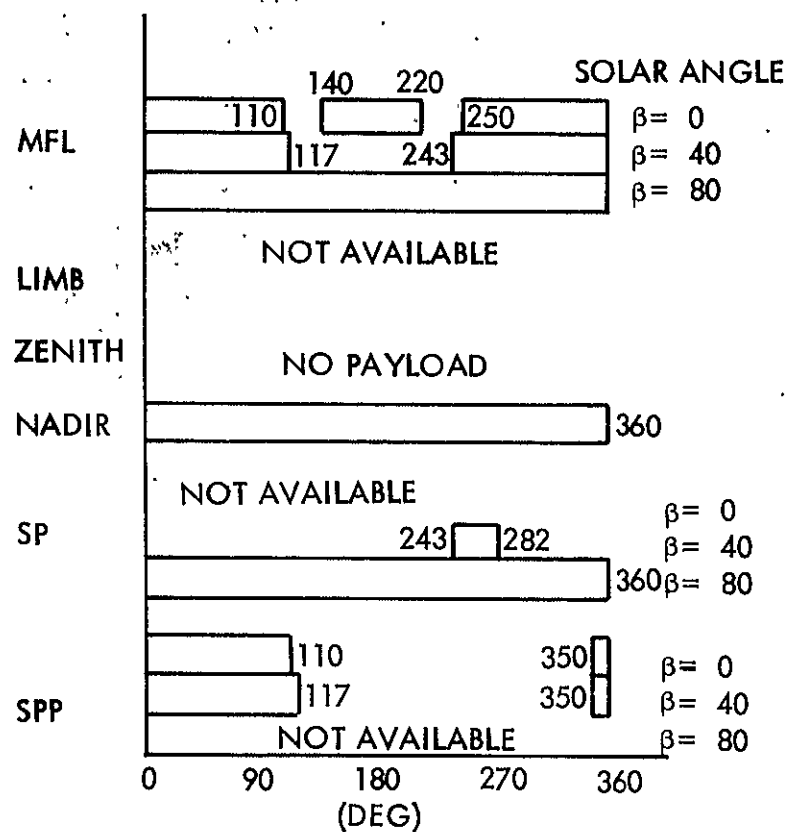
INCREMENT NO. 2





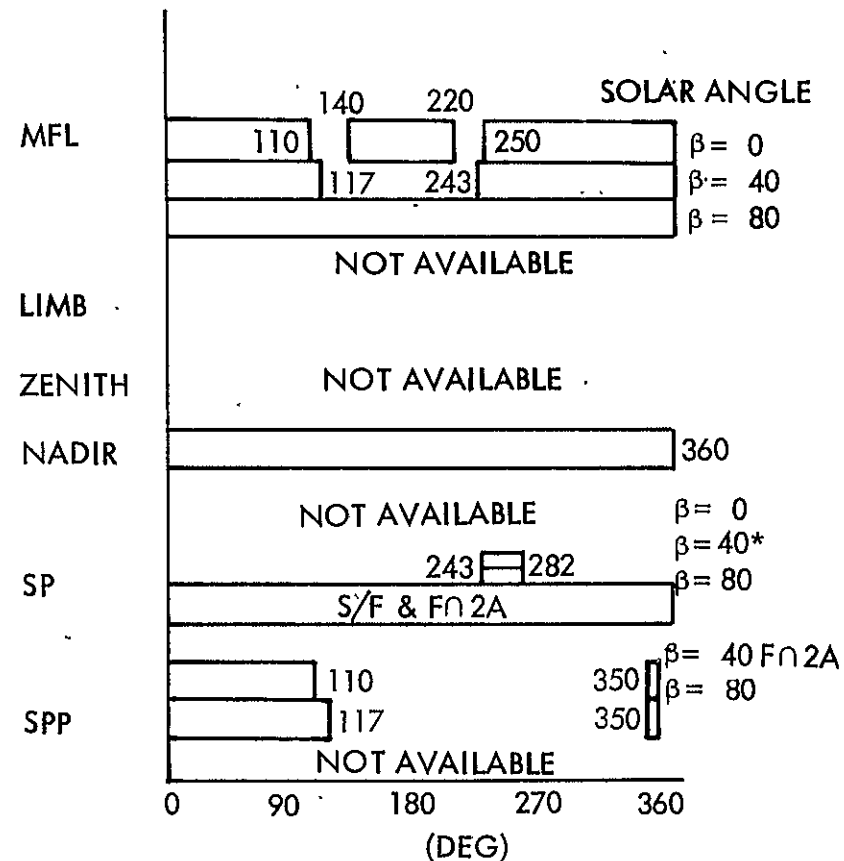
# STO MISSION VIEWING CAPABILITIES XVV, ZLV ATTITUDE

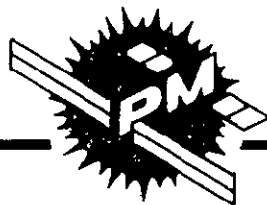
## INCREMENT NO. 1



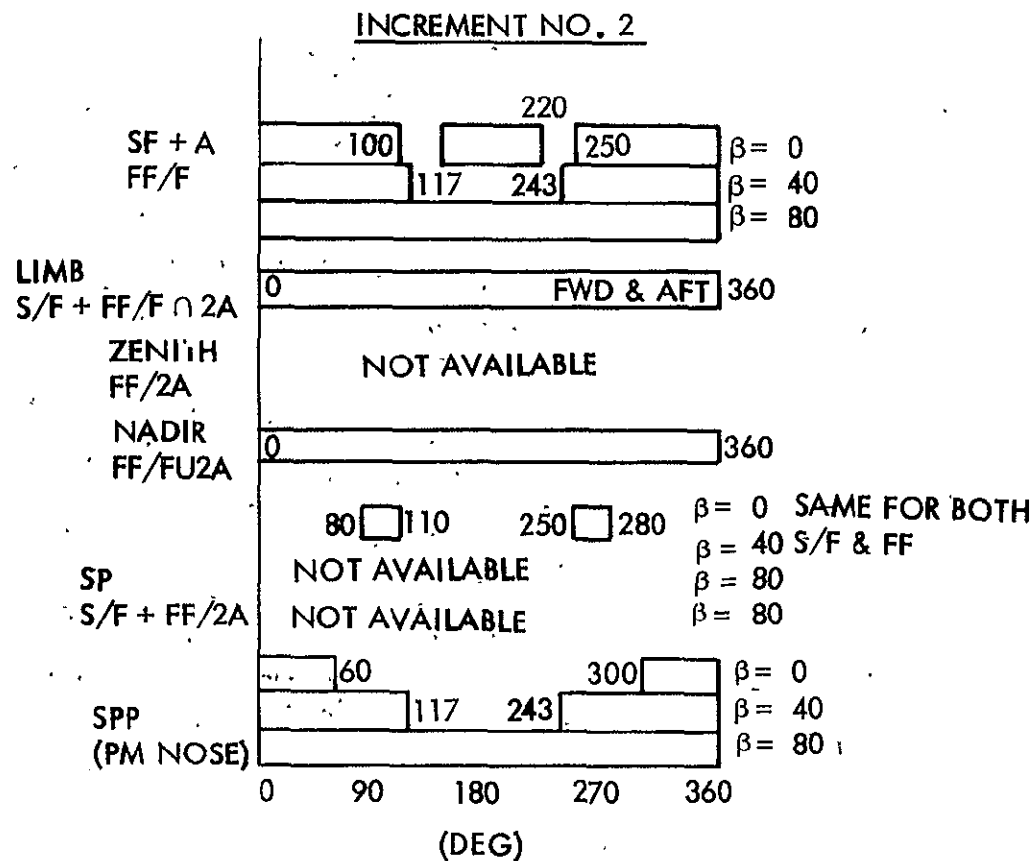
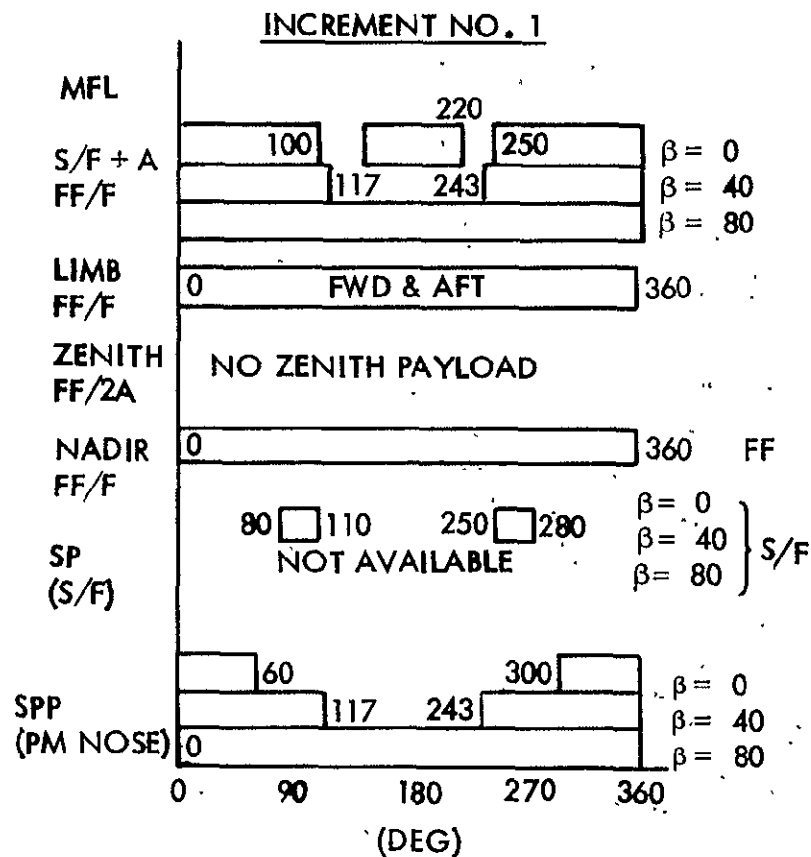
\* $\beta = 40^\circ$  - S/F & F $\cap$ 2A

## INCREMENT NO. 2





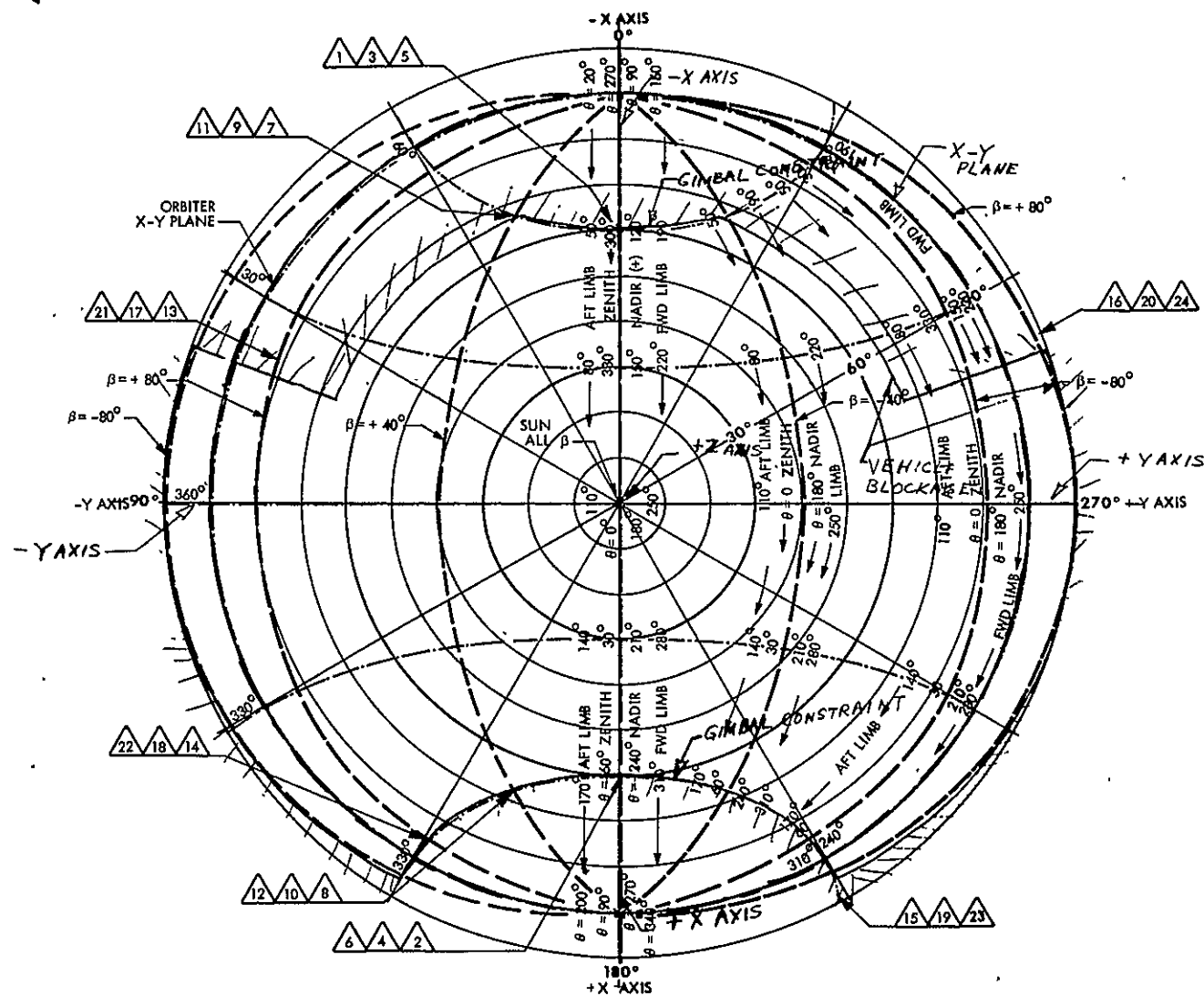
# STO MISSION VIEWING CAPABILITIES XPOP, ZLV





# STO VIEWING COMPOSITE—INCR NO. 1&2

INCR 1 & 2 FFP FWD/XIOP ZSL





## STO MISSION VIEWING CAPABILITIES SUMMARY DATA

PARTIAL EXAMPLE CASE OF INCREMENT NO. 1 ONLY

SYMBOL



FOR BETA = 0

POINT REPRESENTS NADIR AT 120°  
POINT REPRESENTS NADIR AT 240°  
POINT REPRESENTS AFT LIMB AT 50°  
POINT REPRESENTS AFT LIMB AT 170°  
POINT REPRESENTS FWD LIMB AT 190°  
POINT REPRESENTS FWD LIMB AT 310°

SYMBOL



FOR BETA = 40°

POINT REPRESENTS NADIR AT 122°  
POINT REPRESENTS NADIR AT 240°  
POINT REPRESENTS AFT LIMB AT 52°  
POINT REPRESENTS AFT LIMB AT 170°  
POINT REPRESENTS FWD LIMB AT 192°  
POINT REPRESENTS FWD LIMB AT 310°

SYMBOL



FOR BETA = 80°

POINT REPRESENTS NADIR AT 160°  
POINT REPRESENTS NADIR AT 240°  
POINT REPRESENTS NADIR AT 300°  
POINT REPRESENTS NADIR AT 20°  
POINT REPRESENTS AFT LIMB AT 90°  
POINT REPRESENTS AFT LIMB AT 170°  
POINT REPRESENTS AFT LIMB AT 230°  
POINT REPRESENTS AFT LIMB AT 310°  
POINT REPRESENTS FWD LIMB AT 230°  
POINT REPRESENTS FWD LIMB AT 310°  
POINT REPRESENTS FWD LIMB AT 10°  
POINT REPRESENTS FWD LIMB AT 90°



**LOCKHEED**



**IBM**

***TRW***